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WADC TECHNICAL REPORT 53-373

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**A REVIEW OF THE AIR FORCE MATERIALS  
RESEARCH AND DEVELOPMENT PROGRAM**

**LOUISE M. KOEKER**

**MATERIALS LABORATORY**

**BEST AVAILABLE COPY**

**JULY 1954**

**Statement A  
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WADC TECHNICAL REPORT 53-373

**A REVIEW OF THE AIR FORCE MATERIALS  
RESEARCH AND DEVELOPMENT PROGRAM**

*Louise M. Koeker*

*Materials Laboratory*

*July 1954*

Wright Air Development Center  
Air Research and Development Command  
United States Air Force  
Wright-Patterson Air Force Base, Ohio

## FOREWORD

This report was prepared by the Technical Files Section, Administration Office, Materials Laboratory, Directorate of Research, Wright Air Development Center, Wright-Patterson Air Force Base. It was prepared to summarize the major Research and Development effort of the Air Force in the field of materials over the past decade. It is intended that a supplement to this report be issued each year covering each succeeding annual Research and Development program.

The Technical Reports referenced herein have been released to the Armed Services Technical Information Agency.

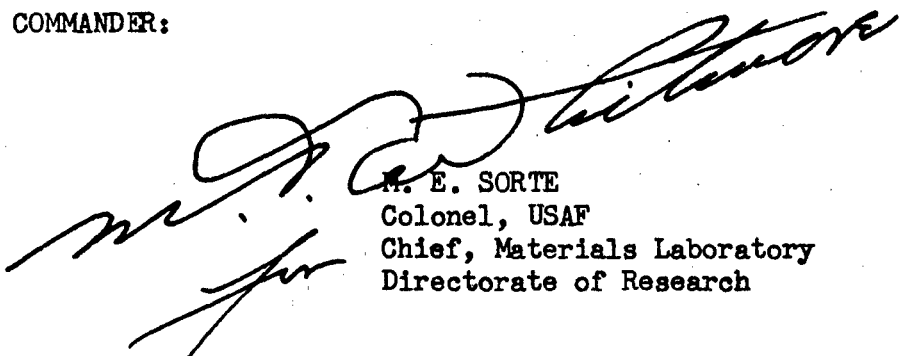
## ABSTRACT

A review of the research and development work sponsored in the field of materials and processes over the past decade is presented. Abstracts of WADC Technical Reports for the period 1 July 1951 to 30 June 1953 are included. A summary of Technical Reports published in the areas of metallurgy, textiles, petroleum products, structural materials, rubbers, plastics, packaging, protective treatments, analysis and measurements are included also.

## PUBLICATION REVIEW

This report has been reviewed and is approved.

FOR THE COMMANDER:



M. E. SORTE  
Colonel, USAF  
Chief, Materials Laboratory  
Directorate of Research

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## INTRODUCTION

The fundamental importance of materials development to the designers of air weapons, components and equipment has been recognized particularly in recent years. This has been reflected in an expanded materials research and development program aimed primarily towards the development of "supersonic" and high performance materials. As stated recently by Dean Boelter<sup>1/</sup>, College of Engineering, University of California, Los Angeles, "A knowledge of the properties of materials is essential to the success of most research and development projects. For indeed it is often the chance choice of an available material which spells the success of the exploitation of the idea or again the diligent search for a material with a given property variation with a variable of the system has resulted in the solution of a problem."

It is with this thought in mind that we have prepared this Technical Report--to disseminate widely the results of our investigation on aircraft materials and processes.

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<sup>1/</sup> Inservice Training for Research and Development, Applied Mechanics Review, V6, No. 11, November 1953.

## SECTION I

### TECHNICAL REPORTS

1 July 1951 - 30 June 1953

#### ADHESIVES, STRUCTURAL

TR 52-156 (Uncl)

December 1952

**SUBJECT:** IMPROVED STRUCTURAL ADHESIVES FOR BONDING METALS  
**INVESTIGATOR:** H. C. Engel  
**CONTRACT:** AF 33(038)-21669  
**CONTRACTOR:** Bloomingdale Rubber Company  
**ABSTRACT:** Work under USAF Contract No. AF 33(038)-21669 has been directed toward the development of an improved structural adhesive for bonding metals. An adhesive designated as PA-101, developed and tested under this contract, meets most of the research objectives and so far as is now known conforms to the requirements of Specification 14164. The PA-101 formulation has been evaluated as a two-part, liquid adhesive.

#### ALLOYS, FERROUS

TR 52-73 (Uncl)

August 1952

**SUBJECT:** MECHANICAL PROPERTIES OF A NEW HIGH-STRENGTH HIGH-TOUGHNESS GENERAL-PURPOSE ALLOY STEEL  
**INVESTIGATOR:** William E. Dirkes, 1st Lt, Robert E. Bowman, Major, Edward L. Horne  
**ABSTRACT:** Mechanical properties of a chrome-nickel-molybdenum-vanadium general purpose medium carbon alloy steel (modified SAE 4330 plus vanadium), developed and fabricated by the Republic Steel Corporation, were determined by the Materials Laboratory, Research Division, Wright Air Development Center, to evaluate the suitability of the steel for aircraft applications where the combination of high strength and toughness are required. The properties of the Republic alloy steel were compared with the properties of an alloy steel, designated as "Hy-Tuf", developed by the Crucible Steel Company for the same purpose and with the properties of the well established SAE 4340 general purpose alloy steel. When heat treated to the same nominal hardness and strength levels, the Republic steel had approximately the same percentages of elongation and reduction of area as the other steels. The Republic alloy steel showed superior Izod impact properties to those of Hy-Tuf and SAE 4340 alloy steels when each was heat treated to a tensile strength approximating 170,000 psi (Rockwell C39) both at room and low temperatures, but its impact properties were not as high as those for Hy-Tuf when heat treated to strength levels around 220,000 psi either at room or low temperatures. Both the Republic alloy steel and Hy-Tuf alloy steel had impact properties superior to 170,000 psi to 240,000 psi

(Rockwell C39 to Rockwell C50), covered in this investigation, at room temperature and at low temperatures (-67°F or below). The end-quench hardenability curve for the Republic alloy steel fell along the minimum curve for SAE 4340 alloy up to a distance of 3/4 inch from the quenched end of the specimen, beyond which distance it approached the median of the hardenability range for SAE 4340. The Republic steel can be successfully welded by the same procedures used for welding SAE 4340 alloy steel.

TR 52-77 (Uncl)

April 1952

SUBJECT: DEVELOPMENT OF LOW ALLOY TI-B STEELS FOR HIGH TEMPERATURE SERVICE APPLICATIONS.  
INVESTIGATOR: G. I. Guarnieri and L. W. Smith  
CONTRACT: W33-038-ac-21094  
CONTRACTOR: Cornell Aeronautical Laboratory, Inc.  
ABSTRACT: Conservation of strategic metals may be accomplished in the production of jet aircraft engine parts provided suitable lean alloy substitutes are made available, capable of operating at elevated temperatures. In this respect, the Ti-B type of ferritic steels have been investigated and their creep and rupture properties evaluated and improved for service temperatures in the neighborhood of 1200°F. It was demonstrated, through testing the properties of a 600 pound heat of 3 Cr- 1 Mo-Ti-B sheet steel with a 2.2 Ti/C ratio, that such a composition not only could be steel mill processed satisfactorily on a semi-commercial basis, but also that 1200°F rupture and creep strength properties, equivalent to the Cr-Ni stainless steels, could be obtained for several hundred hours of life.

A detailed investigation of this steel provided design type creep data for several conditions of heat treatment and hot rolling procedures. Other tests indicated that high hot strength properties could be retained in light gage sheet material provided surface decarburization was minimized during processing. Ceramic coated creep and rupture test specimens of this alloy displayed a life advantage over uncoated specimens at temperatures above 1200°F because of protection against oxidation. Helium arc welded joints of the Cr- 1 Mo-Ti-B sheet steel had inferior hot rupture strength with respect to the parent metal when no filler rod was used. A reasonable approach to parent metal high temperature strengths was obtained with the use of a 347 stainless steel filler rod with the weld bead left on.

As the result of studies made on a variety of compositions of 30 pound laboratory heats of Ti-B steels with varying C, Ti, B, Mo, Cr, W, and V, it was possible to determine the effect of these alloys on the high temperature strengths of the ferritic steels. With increasing quantities of titanium and carbon, marked gain in hot strength was obtained in both the plain C-Ti-B and 3 Cr- 1 Mo-Ti-B steels, provided the Ti/C ratio was maintained in the neighborhood of two to five. Boron variations from 0.010 to 0.10 percent produced no significant effect on

the high temperature strength properties at 1200°F. Molybdenum was most effective in improving the hot strength properties of the Ti-B steels while chromium served more in providing resistance to scaling and oxidation. Tungsten and vanadium, added to the 3 Cr- 1 Mo-Ti-B steels to the maximum extent of about 0.15 percent individually or in combination, caused only minor gain in creep and rupture strength properties.

The unusual high temperature strength of the Ti-B steels is the result of their ability to form a hardened low temperature transformation product of acicular ferrite exceptionally resistant to tempering. This is accomplished as a result of the following:

- (a) Solid solution hardening and diffusion interference effects of both boron and titanium.
- (b) The retention of titanium and carbon in the supersaturated ferrite.
- (c) The dispersion hardening effect of the precipitated titanium carbide.

TR 52-325, Part 1 (Uncl)

December 1952

SUBJECT: ELEVATED TEMPERATURE FATIGUE PROPERTIES OF SAE 4340 STEEL

INVESTIGATOR: W. J. Trapp

ABSTRACT: This report presents the test procedures and results of a fatigue investigation at room and elevated temperatures on SAE 4340 steel, oil quenched and tempered to 160,000 psi in the unnotched and notched condition. The notch used in the investigation is a 60° V-notch with 0.010" radius and 0.025" depth.

The results, which are presented in form of S-N diagrams, normal and nondimensional modified Goodman and stress-range diagrams, reveal the effect of temperature and stress-ratio on the unnotched and notched fatigue properties.

The fatigue tests were supplemented by stress-rupture and creep-rupture tests and by dynamic creep-measurements. The investigation was conducted at room temperature, 600°, 800° and 1000°F.

In general, the fatigue strength was found to decrease with increasing temperature at all stress levels and all stress-ratios except for the life times between  $10^5$  and  $15 \times 10^6$  cycles in the notched condition, where at 600° the value is lower than at 800° and even lower than at 1000°, dependent upon stress ratio. This can probably be related to an increase in brittleness in the 600° region, which is also confirmed by the fact, that the notch sensitivity at 600° was found to be higher than at any of the other temperatures investigated.

The notch-sensitivity factor, based on maximum stress, is dependent upon temperature, stress-level and stress-ratio. It generally

decreases with increasing stress level, increasing temperature and decreasing stress-ratio. The peak of notch-sensitivity is produced at completely reversed load for all temperatures.

The tests indicated that creep is dependent upon mean stress rather than upon maximum stress. Two distinct types of creep-time diagrams were obtained, determined by stress-ratio, mean stress and temperature. A fracture study revealed certain relations between the type of creep diagram and type of fracture, inter and transgranular.

#### ALLOYS, HIGH TEMPERATURE

TR 53-70 (Uncl)

February 1953

SUBJECT: DAMPING, ELASTICITY, AND FATIGUE PROPERTIES OF UNNOTCHED AND NOTCHED N-155 AT ROOM TEMPERATURE AND ELEVATED TEMPERATURES

INVESTIGATOR: L. J. Demer and B. J. Lazan

CONTRACT: AF 33(038)18903

CONTRACTOR: University of Minnesota

ABSTRACT: Data are presented on the damping, elasticity, and fatigue properties of N-155 under rotating bending stress. Unnotched and notched specimens at room temperature, 1350°, and 1500°F are included in this study. Properties at the three temperatures are compared on two bases, equal stress and equal stress ratio. The change in vertical deflection and run-out for notched specimens are associated with the first evidence of the formation of a fatigue crack. Curves for these first-evidence-of-crack points plotted against stress are compared with the usual S-N fracture diagrams. Effective stress concentration factors are determined from both the fracture and first-evidence-of-crack data and the latter values are found to be nearly independent of the number of fatigue cycles. Data are presented for both unnotched and notched specimens on the dynamic proportional limit and its relationship to the fatigue strength. Equations are developed for interpreting rotating cantilever beam data so that the effective length of specimen fillets, specific damping energy, and dynamic modulus of elasticity may be calculated.

TR 52-226, Part 1 (Uncl)

March 1953

SUBJECT: INVESTIGATION OF AXIAL LOADING FATIGUE PROPERTIES OF HEAT RESISTANT ALLOY N-155

INVESTIGATOR: B. J. Lazan and F. De Money

CONTRACT: AF 33(038)20840

CONTRACTOR: University of Minnesota

ABSTRACT: Dynamic creep and rupture data are presented on N-155 at room temperature and 1000°F, correlated to some extent with prior work. Temperature increases were observed in certain temperature and stress ranges immediately after the application of alternating stress

to a test specimen. These are discussed in terms of the internal damping capacity of the material and the possibility of utilizing these observed temperature increases as a qualitative indication of damping is suggested. A vibration analysis of the Minnesota direct stress fatigue machine is presented and used to correlate calibration data procured by three independent methods.

TR 52-226, Part 2 (Uncl)

February 1953

SUBJECT: INVESTIGATION OF AXIAL LOADING FATIGUE PROPERTIES OF HEAT RESISTANT ALLOY N-155, PART 2. AN EXPLORATORY INVESTIGATION OF THE EFFECT OF TEMPERATURE, TIME, AND STRESS ON FRACTURE CHARACTERISTICS AND METALLOGRAPHIC STRUCTURE OF N-155 AND HARDNESS OF N-155 AND S-816

INVESTIGATOR: Fred W. DeMoney

CONTRACT: AF 33(038)18903

CONTRACTOR: University of Minnesota

ABSTRACT: An exploratory study of effect of the test variables on the macroscopic appearance of the fracture surface was continued. Fracture profiles were investigated microscopically and an attempt made to quantitatively analyze the nature of the fracture profile. From this analysis is shown that the tendency for an intercrystalline fracture to occur decreases with increasing stress and stress ratio. Investigation of the metallographic structure and hardness of unstressed N-155 verifies prior work concerning the precipitation hardening characteristics of this material. Rockwell "B" hardness tests were conducted on both the surface and longitudinal sections of the stressed specimens in the longitudinal variable stress regions. Tukon Vickers diamond pyramid hardness tests were also conducted on transverse sections of rotating beam fatigue specimens in the transverse variable stress regions. The study of effect of stress variables, while not completely investigated, indicate an acceleration of the precipitation hardening phenomenon as revealed by hardness tests. The acceleration of the precipitation hardening phenomenon is not observed in the metallographic structure of the material.

TR 52-227 (Uncl)

November 1952

SUBJECT: PROPERTIES OF TEMPERATURE-RESISTANT MATERIALS UNDER TENSILE AND COMPRESSIVE FATIGUE STRESS

INVESTIGATOR: B. J. Lazan and E. Westberg

CONTRACT: AF 33(038)18903

CONTRACTOR: Syracuse University

ABSTRACT: Newly developed grips and machine improvements are described for fatigue loading under direct stress (tension-compression) ratios of alternating to mean stress from zero to infinity. Data are presented to indicate the uniformity of stress distribution possible with these grips and accuracy of the average stress. Dynamic creep, rupture and ductility data are reported on N-155, S-590 and Vitallium

at 1350° and 1500° F under direct stress combinations from static to reversed loading. Stress range diagrams (alternating stress versus mean stress) are presented to indicate the stress combination which will produce rupture and various degrees of creep in 5 to 1500 hours. Percent elongation data are analyzed in terms of alternating-to-mean stress ratio and stress magnitude, and it is shown that both are significant variables. Elongation up to the start of third stage of creep is also analyzed in terms of stress ratio and stress magnitude and only stress magnitude was found to be significant. The implications of these findings are discussed.

TR 52-243 (Uncl)

November 1952

SUBJECT: DAMPING, ELASTICITY, AND FATIGUE PROPERTIES OF TEMPERATURE-RESISTANT MATERIALS

INVESTIGATOR: B. J. Lazan and L. J. Demer

CONTRACT: AF 33(038)18903

CONTRACTOR: Syracuse University

ABSTRACT: The damping, elasticity and fatigue properties of several temperature-resistant materials were investigated in rotating cantilever-beam testing equipment. The room and elevated temperature tests were designed to reveal changes in damping energy and dynamic modulus of elasticity during constant cyclic stress fatigue tests at engineering stress levels. Usual S-N fatigue curves are presented in addition to a series of new diagrams designed to show the effects of both stress magnitude and stress history on the damping and elasticity properties. Two methods for comparing the damping energies of a group of materials are offered and the merits of each discussed. Diagrams are also presented to facilitate comparison of the elasticity properties among materials tested at a given temperature.

TR 52-253 (Uncl)

December 1952

SUBJECT: METALLOGRAPHIC STUDIES ON N-155 SPECIMENS EXPOSED TO STATIC AND DYNAMIC STRESS AT ELEVATED TEMPERATURES

INVESTIGATOR: F. R. Morral and B. J. Lazan

CONTRACT: AF 33(038)18903

CONTRACTOR: Syracuse University

ABSTRACT: Work reported herein represents a continuation of earlier metallographic studies on heat-resistant alloys. The specimens studied in this program were N-155 previously tested under fatigue stress having various stress ratios. An attempt was made to determine the effect of each of the four test variables; time, temperature, static stress, alternating stress. Visual and macroscopic classifications of the fractures were attempted and microscopic structure and microhardness data are reported.

March 1953

SUBJECT: ELEVATED TEMPERATURE FATIGUE TESTING OF TURBINE BUCKETS,  
Part 2. FATIGUE TESTS OF TURBINE BUCKETS UNDER STATIC  
AXIAL AND SUPERIMPOSED VIBRATIONAL BENDING LOADS

INVESTIGATOR: Dr. Albrecht Herzog, Ing.

ABSTRACT: The fatigue investigation of turbine blades in a special device, permitting the application of static axial and superimposed vibrational bending loads by means of an electromagnet, is discussed. The excitation of the vibration of the axially loaded bucket was adjusted to the fundamental frequency of this system. The most important factors causing damping effects and energy losses during vibration are considered. Special attention is given to the measuring methods for obtaining stress and deflection values of the vibrating bucket under dynamic load. The tests were conducted at room and at elevated temperatures. The results are discussed and compared with fatigue tests under similar conditions using simple specimens and standard testing devices.

TR 6615 (Uncl)

August 1951

SUBJECT: THE DEVELOPMENT OF FORGING AND CASTING ALLOYS FOR  
TURBINE BUCKETS

INVESTIGATOR: Ralph P. DeVries, Jr., and Gunther Mohling, Ph.D.

CONTRACT: AF 33(038)11669

CONTRACTOR: Allegheny Ludlum Steel Corporation

ABSTRACT: This project was undertaken with the object of further investigating the forging and cast turbine bucket alloys developed under the preceding contract AF 33(038)-2040. The effects of various compositional variations were studied on the forging alloy V-912, 34.9 cobalt, 6.5 tungsten, 1.6 columbium, 20.0 chromium, 20.0 nickel, 3.0 molybdenum, 0.3 silicon, 1.0 manganese, 0.3 carbon, balance iron, and the cast alloy W-834, 29.5 cobalt, 8.0 tungsten, 0.5 carbon, 25.0 chromium, 20.0 nickel, 3.0 molybdenum, 0.5 silicon, 1.0 manganese, balance iron.

It was found that the percentage of elements in these alloys was very close to the optimum ratios to produce sufficient stress rupture and room temperature strengths required of turbine bucket alloys.

TR 6640 (Uncl)

October 1951

SUBJECT: SILICA-KAOLIN PRECOAT FOR INVESTMENT CASTING

INVESTIGATOR: William F. Davenport, Captain, USAF, and Adolph Strott

ABSTRACT: An investigation was conducted to study the feasibility of using kaolin as the source for alumina in the recently discovered alumina-silica precoat, or mold facing material.

Precoats were prepared using kaolin as the alumina carrier in both molecular and percentile variations. These were evaluated by casting a heat resistant type alloy, a stainless steel, and an alloy steel into the investment molds faced with each particular precoat composition. Kaolin was found to be satisfactory as the alumina source although some



shifting of previously determined composition limits was noted. No difference in precoat properties was found to exist between molecular and percentile variations other than that which was accounted for due to percentile differences.

### ALLOYS, NONFERROUS, ALUMINUM

TR 53-40 (Uncl)

February 1953

SUBJECT: EFFECT OF MEAN STRESS ON THE FATIGUE LIFE OF ALCLAD 24S-T3 AND ALCLAD 75S-T6 ALUMINUM ALLOY  
INVESTIGATOR: I. Edward Wilks and Barnley M. Howard  
PURCHASE ORDER: AF 33(038)51-4061, Part A  
CONTRACTOR: National Bureau of Standards, U. S. Department of Commerce  
ABSTRACT: An investigation has been conducted to determine the effect of mean stress on the axial loading fatigue life of two alclad aluminum alloys in sheet form with stress concentrations. The alloys were 24S-T3 and 75S-T6. The specimens were rectangular, 0.8 inches wide and 6.5 inches long with a 0.125 inch diameter hole drilled at the center. Tests were conducted using a lever type machine.

The range of mean stress was from 20,000 lb/in<sup>2</sup> tension to 20,000 lb/in<sup>2</sup> compression and the alternating stress ranged from zero to  $\pm 30,000$  lb/in<sup>2</sup>. Some of the specimens tested in all compression stress range failed with axial as well as transverse cracks emanating from the edge of the hole.

The results showed that: (1) The effect of mean stress on 24S-T3 and 75S-T6 was the same, (2) At any alternating stress amplitude fatigue life increases as the mean stress decreases, (3) The effect of mean stress on fatigue life is increased as the alternating stress amplitude is decreased and (4) As the tensile mean stress decreases the allowable amplitude of alternating stress increases, in the compression range the allowable amplitude of alternating stress also increases as the compressive mean stress increases, at least as far as the range of this test.

TR 53-151 (Uncl)

May 1953

SUBJECT: STUDY OF HARD COATING FOR ALUMINUM ALLOYS  
INVESTIGATOR: F. G. Gillig  
CONTRACT: AF 18(600) 98  
CONTRACTOR: Cornell Aeronautical Laboratory, Inc.  
ABSTRACT: A study has been made of the effects of hard oxide coatings produced by the MHC process on the properties of five wrought and two cast aluminum alloys. Coating thicknesses ranging from 0.0005 inch to 0.005 inch were studied. Of the many properties that were studied, the abrasion resistance of the coatings and their effect on the fatigue

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strength of the parent metal are the most significant. The abrasion resistance of the hard coatings is far in excess of that of coatings produced by standard anodizing treatments and has been demonstrated to be equal to or better than that of thin cyanide coatings on steel. In addition to this, the coatings impart increased corrosion resistance to the aluminum alloy surface. The abrasion resistance decreases with exposure to humidity and atmospheric conditions but proper post-treatments, other than boiling water which is used for sealing regular anodized coatings, will undoubtedly prevent this. The most serious shortcoming of the coatings has been found to be their drastic lowering of the fatigue strength of the coated alloy. Decreases as much as 65% in the base metal fatigue strength have been found. The effect is not proportional to coating thickness and coatings of 0.001 inch produce practically the same effect as 0.005-inch coatings.

TR 52-307, Part 1 (Uncl)

December 1952

SUBJECT: FATIGUE PROPERTIES OF ALUMINUM ALLOYS AT VARIOUS DIRECT STRESS RATIOS, Part I - ROLLED ALLOYS  
INVESTIGATOR: B. J. Lazan and A. A. Blatherwick  
CONTRACT: AF 33(038) 20840  
CONTRACTOR: University of Minnesota  
ABSTRACT: Newly developed equipment for axial stress fatigue testing in the tension-compression range is described. Fatigue data on 14S-T6, 24S-T4, and 75S-T6 aluminum alloys are presented as S - N curves and stress range diagrams to illustrate and analyze the effects of: (a) stress ratios in the range from static tension to reversed axial stress, (b) stress magnitude which causes failure in the range from  $10^5$  to  $10^7$  cycles, and (c) severity of circumferential notches having four different theoretical stress concentration factors in the range between 1.0 and 3.4. The extreme flatness of the stress range diagrams for severely notched specimens at long life is discussed in terms of the large reduction in mean load carrying capacity resulting from the addition of relatively small alternating stress. Unitless stress range diagrams are presented which indicate how material, life, and specimen type affect the combinations of alternating and mean stress which cause failure in a specified number of cycles. Data on the reduction in fatigue strength caused by notches are diagrammed to clarify the significance of mean stress, alternating stress, stress ratio, and cycles to failure as factors in fatigue notch sensitivity. The fatigue properties determined in this program are compared with prior work. The low fatigue strengths observed for 75S-T6 are briefly discussed.

TR 52-307, Part 2 (Uncl)

December 1952

SUBJECT: FATIGUE PROPERTIES OF ALUMINUM ALLOYS AT VARIOUS DIRECT STRESS RATIOS, Part II - EXTRUDED ALLOYS  
INVESTIGATOR: B. J. Lazan and A. A. Blatherwick  
CONTRACT: AF 33(038) 20840  
CONTRACTOR: University of Minnesota

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**ABSTRACT:** Axial-stress fatigue tests were performed at various stress ratios on extruded aluminum alloys 14S-T6, 24S-T4, and 75S-T6 using one unnotched and one notched type of round specimen. The data are presented in the form of S-N curves and stress-range diagrams to analyze the effect of: (a) stress ratio, ranging from static tension to reversed axial stress, (b) stress magnitudes which cause failure in the range from  $10^3$  to  $10^7$  cycles, and (c) stress concentration resulting from a circumferential V-notch. The notch-sensitivity data are further analyzed by diagrams which display the importance of stress ratio, stress level, and life on fatigue strength reduction. The fatigue properties of the three extruded alloys are compared both with each other and with rolled aluminum alloys.

TR 52-251, Part 1 (Uncl)

September 1952

**SUBJECT:** INVESTIGATION OF COMPRESSIVE-CREEP PROPERTIES OF ALUMINUM COLUMNS AT ELEVATED TEMPERATURES

**INVESTIGATOR:** R. L. Carlson and A. D. Schwoppe

**CONTRACT:** AF 33(038) 9542

**CONTRACTOR:** Battelle Memorial Institute

**ABSTRACT:** An experimental investigation of the behavior of 24S-T4 (stabilized) aluminum columns at three elevated temperatures has been conducted. Tests were performed on long- and short-hinged-end columns of five slenderness ratios. By using an adjustable end eccentricity, it was possible to fix the eccentricity for a column of a given slenderness ratio and thereby obtain comparable results for different loads. Deflection measurements were taken at the mid-point throughout the duration of each test, and curves of deflection versus time with load as the parameter were obtained for each slenderness ratio. Test results indicate that, for a column of a given slenderness ratio and eccentricity, there is a limiting load below which collapse due to creep will not occur. It is concluded that this lower limit should be considered the limiting or allowable load. It is suggested that an approximate method of the type introduced in the report should be employed to determine this load.

TR 6513 (Uncl)

October 1951

**SUBJECT:** FATIGUE PROPERTIES OF TUNGSTEN-ARC BUTT-WELDED WROUGHT ALUMINUM ALLOYS

**INVESTIGATOR:** Ture T. Oberg and Edward J. Ward, Captain, USAF

**ABSTRACT:** A study has been made of the fatigue characteristics in reversed bending of argon gas shielded tungsten arc butt welded joints in 14S-T and 75S-T sheet. The effects of post weld heat treating and filler material were investigated. The Aluminum Company of America furnished the specimens for the investigation which was conducted by the Materials Laboratory, Research Division, Wright Air Development Center.

The static tensile strengths of the welded joints varied from 46 to 69% of the tensile strengths of the sheet materials. The fatigue strengths were from 39 to 65% of the fatigue strength of the sheet material, depending upon the sheet material, the filler material and post weld heat treatment. The argon gas shielded tungsten arc

welding process therefore does not produce joints in 75S-T or 14S-T alloys of satisfactory fatigue strength.

TR 6675 (Uncl)

October 1951

SUBJECT: ULTRASONICS APPLIED TO SOLIDIFICATION AND SOLID-STATE TRANSFORMATION  
INVESTIGATOR: J. Byron Jones  
CONTRACT: AF 33(038) 11208  
CONTRACTOR: Aeroprojects, Incorporated  
ABSTRACT: Ultrasonic energy was applied to 24S and 75S aluminum alloys after solution heat treatment, and the effect on age hardening evaluated, primarily by means of Rockwell hardness readings, and tensile tests. The effects were small and indicate that high intensity elastic energy retards precipitation hardening.

Ultrasonic energy was applied to eighteen cubic inch melts of pure magnesium, pure zinc, a 3.5 percent magnesium-zinc alloy, and magnesium-zirconium alloys. Grain refinement was accomplished and sounder ingots resulted from the use of ultrasonics. Zirconium sponge was alloyed with pure magnesium by the application of ultrasonics.

ALLOYS, NONFERROUS, MAGNESIUM

TR 53-18, Part 1 (Uncl)

January 1953

SUBJECT: POWDER-FABRICATED MAGNESIUM ALLOYS, Part 1. DEVELOPMENT OF HIGH-STRENGTH SHEET FROM POWDER-FABRICATED Mg ALLOYS CONTAINING Zn, Zr, AND Al  
INVESTIGATOR: H. A. Johnson, 2d Lt, USAF, ed.  
CONTRACT: High strength sheet has been produced through development of rolling techniques for ZK + A20 powder extrusions. Excellent properties and rollability have been obtained by rapidly heating ZK60 powder extrusions to the rolling temperature, hot rolling in one heat, and warm rolling to the desired gage. High quality ZK60 powder fabrications which have corrosion rates equal to those of billet material have been produced. Illustrative properties of ZK60 sheet hot rolled on the 8" mill under the above technique are compared below with typical values of FS-H24, our present high strength commercial sheet alloy:

Alloy	Hot Rollability	ZE	1000 psi				Corrosion Rate (mcd)
			TYS	CYS	TS	NBE	
ZK60	450-950F	6	51	43	59	7	0.6-1.0
FS-H24	500-900F	16	32	27	42	11	0.4-0.6

As development work has been completed on laboratory equipment, we are now ready to make preliminary evaluation of powder fabricated ZK60 sheet on production equipment. Further improvement of the properties of ZK60 by small melt additions of Ca, Ce, Th, Cd, and Ag will be tried on the 3" mill.

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January 1953

SUBJECT: POWDER-FABRICATED MAGNESIUM ALLOYS, Part 2. LARGE-SCALE EXTRUSION OF ZK60A ALLOY POWDER  
 INVESTIGATOR: H. A. Johnson, 2d Lt, USAF, ed.  
 CONTRACT: W33(038)ac-19884(19479)  
 CONTRACTOR: Dow Chemical Company  
 ABSTRACT: Approximately 7,000 pounds of ZK60A alloy powder have been extruded into various shapes on production equipment.

A kiln type powder heater, a portable powder loader, and a small extrusion container extension have been constructed and operated. Other equipment necessary for production extrusion of ZK60A alloy powder has been studied.

It has been demonstrated that high purity ZK60A alloy powder possesses a corrosion rate similar to that of billet extrusions.

It has been demonstrated that blisters are caused by flux and rust inclusions. The best method of eliminating blisters is screening the powder to -20 mesh, and heating it to 650°F prior to extrusion.

Typical properties and properties which 95% or more of the powder extrusions will meet based on the thickness of the extrusion are as follows:

Thickness Inches	Typical Properties				95% Equal or Over			
	%El	1000 psi			%El	1000 psi		
		TYS	CYS	UTS		TYS	CYS	UTS
Less than 0.2	17	38	37	48	7	32	33	42
0.2 and Greater	17	39.5	41	50	10	36	36	47

TR 52-169 (Uncl)

September 1952

SUBJECT: MAGNESIUM ALLOY RESEARCH STUDIES  
 INVESTIGATOR: A. Jones, J. H. Lennon, R. R. Nash, W. H. Chang and E. G. MacPeck  
 CONTRACT: W-33-038-ac-22542  
 CONTRACTOR: Rensselaer Polytechnic Institute  
 ABSTRACT: Diagrams are presented to show the constitution at 500° and 700°F for the magnesium-lithium-aluminum and magnesium-lithium-zinc alloy systems. These diagrams were determined mainly by microscopic examination of alloys quenched from elevated temperatures. Corrosion and loss of lithium prevented the successful use of x-ray diffraction and electrical resistivity measurements at elevated temperatures. The solubility for aluminum and for zinc was less at 500° than at 700°F but the solubility for lithium was almost the same at these two temperatures.

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The study of dilute magnesium alloys found a good combination of properties for magnesium-1.0% zinc-0.4% cerium. The addition of cerium refined the grain structure and introduced a small amount of a second constituent. The best properties were obtained with a fine equiaxed grain structure produced by warm rolling and annealing just above the recrystallization range. These conditions of structure and properties were not obtainable by a single cycle of cold rolling and annealing.

Single crystals of high purity magnesium were grown by controlled solidification in a gradient furnace. The furnace and the mold remained stationary and only the temperature gradient moved. The conditions of growth were found to be more critical for single crystals of magnesium-aluminum and magnesium-zinc alloys. No alloy single crystals were produced but favorable conditions for their growth were approached. Causes and remedies are discussed for the failure to produce magnesium alloy single crystals.

TR 6594 (Uncl)

July 1951

SUBJECT: CLADDING MAGNESIUM

INVESTIGATOR: George W. Orton, Captain, USAF, and A. David Gibson, Captain, USAF

ABSTRACT: Results of experiments to clad a strong magnesium alloy with aluminum alloys and anodic magnesium alloys are reported. It was demonstrated that magnesium alloys are easily clad with other magnesium alloys but cladding with aluminum is more difficult.

ALLOYS, NONFERROUS, TITANIUM

TR 53-26 (Uncl)

April 1953

SUBJECT: INVESTIGATION OF HEAT TREATMENT OF COMMERCIAL TITANIUM  
BASE ALLOYS

INVESTIGATOR: L. Luini

CONTRACT: AF 33(038)23302

CONTRACTOR: Curtiss-Wright Corporation, Wright Aeronautical Division, Woodridge, New Jersey

ABSTRACT: An exploratory survey of the heat treatment response of commercial titanium alloys (Ti-150A, RC-130B, RC-130A and MST-3Al-5Cr alloys) shows a wide range of possible hardness and microstructural characteristics. The hardening is primarily dependent on the solid state transformation of the beta phase. An age hardening reaction which is apparently associated with beta decomposition and precipitation has been shown. Brittleness and notch sensitivity appear to be characteristic of age hardening to high hardness. Low ductility is shown by the MST-3Al-5Cr alloy and the Ti-150A alloy exhibits notch sensitivity. Tensile strengths up to 191,000 psi for Ti-150A, 194,000 psi for RC-130B, and 192,000 psi for MST-3Al-5Cr have been demonstrated. Elongations in the range of 2 to 8% were shown for these high strengths. Stresses imposed by the machining operation appear to lower the observed endurance limit.

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May 1953

SUBJECT: TITANIUM ALLOYS FOR ANALYTICAL STANDARDS  
INVESTIGATOR: H. W. Lownie, Jr., D. L. Chase, and W. M. Henry  
CONTRACT: AF 33(600) 6850  
CONTRACTOR: Battelle Memorial Institute  
ABSTRACT: The purpose of this work was to prepare titanium alloys for tentative chemical standards. Titanium alloys have been melted, chipped, and analyzed to serve as tentative chemical standards. The chemical and spectrographic procedures used are described in detail. Analytical results are close to the intended compositions and also show the individual samples to be uniform within the limits of accuracy of the analytical techniques.

This report covers the melting and the chemical and spectrographic analyses of sixteen ten-pound titanium ingots as specified and listed in Table 1. Analytical methods and results are presented in detail.

TR 52-16 (Uncl)

December 1952

SUBJECT: PHASE DIAGRAMS OF THE TITANIUM-ALUMINUM, TITANIUM-CHROMIUM-IRON, AND TITANIUM-OXYGEN ALLOY SYSTEMS  
INVESTIGATOR: R. J. Van Thyne, E. S. Bumps, H. D. Kessler and M. Hansen  
CONTRACT: AF 33(038) 8708  
CONTRACTOR: Armour Research Foundation., Illinois Institute of Technology  
ABSTRACT: Partial phase diagrams are presented for the systems titanium-aluminum, titanium-chromium, titanium-iron, titanium-chromium-iron, and titanium-oxygen. All studies are completed except for the titanium-chromium-iron system, which requires further confirmatory work in certain areas. The results are outlined in Section IV of this report (page 78).

TR 52-202 (Uncl)

February 1953

SUBJECT: A PRELIMINARY INVESTIGATION ON THE EFFECTS OF SURFACE TREATMENTS ON THE FATIGUE STRENGTH OF TITANIUM ALLOYS Ti-150A AND RC-130B  
INVESTIGATOR: Heinrich K. Adenstedt, Frank E. Binns, Lt, USAF, and Robert J. Rooney  
ABSTRACT: The evaluation of the effects of various treatments on the fatigue properties of titanium bar stock alloys Ti-150A and RC-130B was made. The various treatments of Ti-150A and their corresponding fatigue endurance limits are as follows:

1. Machined and polished - 68,000 psi
2. Ground - 63,000 to 70,000 psi
3. Ten percent permanently stretched and ground - 54,000 psi (wide scatter of data)
4. Ground and scaled - 56,000 psi
5. Machined notched - 40,000 psi
6. Ground and notched - 21,000 psi

The fatigue strength varied from about 35 to 45 percent of the tensile ultimate strength for the different treatments, except for the notched condition as would be expected. RC-130B gave endurance limits of about 67,000 psi (approximately 45 percent of tensile ultimate strength) for the ground, unnotched condition, and about 24,000 psi for the ground notched material. The wide range of values for the ground Ti-150B alloy and for the 10 percent stretched and ground Ti-150A alloy may have been due to various degrees of surface cold work, and surface discontinuities, caused by grinding and cold work. In addition, radiography identified tungsten inclusions which were probably a contributing factor. In general, the surface treatment has a marked effect upon the fatigue strength of titanium and its alloys. For the conditions tested, a machined and polished surface produced the optimum fatigue properties.

TR 52-245 (Uncl)

May 1953

SUBJECT: TITANIUM ALLOYS FOR ELEVATED TEMPERATURE APPLICATION  
INVESTIGATOR: William F. Carew, Frank A. Crossley, Harold D. Kessler,  
and Max Hansen  
CONTRACT: AF 33(038) 22806  
CONTRACTOR: Armour Research Foundation, Illinois Institute of Technology  
ABSTRACT: The theoretical aspects of the development of titanium alloys for use at elevated temperatures are presented. The results of a preliminary tensile test survey of binary alloys are given. These results indicate that aluminum is one of the most promising strengtheners of titanium at elevated temperatures. Therefore, titanium-aluminum alloys were used as a base for ternary alloys which were surveyed by means of the hot hardness test. From the results of this survey twelve ternary alloys and two binary titanium-aluminum alloys were selected for further differentiation by creep rupture testing. Some creep rupture results at 425° and 550°C are reported and give considerable promise for the development of alloys having equivalent if not better properties than Type 403 stainless steel (13 Cr, balance Fe).

Concurrently with the hot hardness survey programs, stabilization studies were made as an aid in developing heat treatments for these alloys.

Oxidation studies were made on some of the alloys and are reported. The results show that generally the oxidation rate decreases with time. Also, the results indicate that at 550° and 675°C the oxidation resistance of some of the alloys may be as good as that of Type 403 stainless steel.

TR 52-249 (Uncl)

June 1952

SUBJECT: DEVELOPMENT OF TITANIUM-BASE ALLOYS  
INVESTIGATOR: C. H. Lorig, et al  
CONTRACT: AF 33(038)-3736  
CONTRACTOR: Battelle Memorial Institute

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**ABSTRACT:      Selection and Heat Treatment of Promising Alloys**

Experimental work conducted under this contract prior to May, 1951, had shown that the beta-stabilizing elements, chromium, iron, manganese, molybdenum, and vanadium, offered the most promise in the development of titanium alloys. The alpha-stabilizing, interstitial elements, carbon, oxygen, and nitrogen, were potent strengtheners, but decreased ductility disproportionately to their strengthening ability.

Based on these observations, most of the exploratory alloys melted and tested during the past contract year contained one or more of the five metallic elements mentioned above. Several ternary alloys showed much promise as potential high-strength alloys. The Ti-Mn-Cr, Ti-Mn-Mo, and Ti-Fe-Mo systems were of interest in that high-strength properties were obtained over a wide range of compositions. Several complex alloys containing small amounts of all five beta-stabilizing elements also had outstanding properties.

Although there were a number of other compositions which might be of equal interest, twelve alloys were selected for more detailed studies of the effects of heat treatments on tensile properties. Tensile and bend properties of hot-rolled sheet from exploratory heats of these alloys are summarized in Figure I. All of the alloys selected except the Ti-15%Cr alloy had tensile strengths of the order of 200,000 psi. The current heat-treatment program is expected to produce improvements in the ductility of these alloys without excessive loss of strength. The Ti-15%Cr alloy was selected because of its excellent bend ductility at the 150,000 psi strength level.

Several of these alloys have been produced as five- and ten-pound ingots and fabricated into sheet and bar stock for testing. During the next year, ingots weighing 20 or more pounds of the most interesting alloys of this group will be melted, fabricated, and evaluated.

The evaluation of the selected alloys was started shortly before the close of the past contract year. Only a limited amount of data is available at this time. The following seven compositions were melted as duplicate one-pound ingots to test the reproducibility of mechanical properties from heat to heat:

Ti-3.5%Cr-3.5%V	Ti-5%Mn-2%Fe
Ti-3.5%Cr-3%Mn	Ti-5%Mo-4%Fe
Ti-2.5%Cr-5%Mn	Ti-5%Cr-1.5%Fe
Ti-5%Mn-2%Mo	

In the as-hot-rolled condition, the mechanical properties of the two heats of each alloy varied considerably. Other specimens from the same heats will be tested in various heat-treated conditions to determine whether such treatments will produce more consistent properties.

Four of the selected alloys, having the nominal compositions listed below, were melted as five-pound ingots, fabricated to sheet, and tested in the as-hot-rolled and annealed conditions.

Ti-3.5%Cr-3.5%V  
Ti-2.5%Cr-5%Mn  
Ti-1%Cr-1%Fe-3%Mn-1%Mo-1%V  
Ti-1%Cr-1%Fe-1%Mn-1%Mo-1%V

In general, the properties of all four heats were within the high strength range in the as-hot-rolled condition, but considerable variations were found in specimens taken from different sections of the same heat. Chemical analyses of these specimens revealed relatively large differences in composition, in some cases. Annealing at 1300° - 1400°F followed by air cooling produced much more consistent properties within individual heats. Average properties of the four alloys after annealing at these temperatures are given in Figure II. Specimens annealed at 1300°F had excellent ductility at strength levels of 137,000 to 150,000 psi. Annealing at 1400°F resulted in somewhat higher strengths and much lower ductility. A 1500°F anneal produced relatively poor properties in all of the alloys and erratic test results in two individual alloys.

#### Heat Treatment of Exploratory Alloys

While ingots of the selected alloys were being prepared, several groups of exploratory alloys for which sheet material was already available were heat treated and tested to determine the general effects of different thermal cycles on tensile properties.

Sheet specimens annealed at 1300°F and air cooled generally had excellent ductility but relatively low strength. Increasing the annealing temperature to 1400° - 1500°F resulted in higher strengths and lower ductility. In some cases, strengths comparable with those obtained in the as-hot-rolled condition were produced by the latter treatments. Solution treatments in the alpha-beta- or beta-phase fields (1300° - 1600°F) followed by quenching and subsequent aging in the temperature range 600° - 825°F produced high strengths in many alloys, but, in general, ductility was very low. However, some of the alloys, as solution treated, had excellent intermediate strength properties. For example, the Ti-3.5%Cr-3.5%Mn alloy solution treated at 1450 F and water quenched had an ultimate tensile strength of 145,800 psi with an elongation of 24 percent in one inch.

In conjunction with this exploratory heat-treatment program, the effects of quenching media and low-temperature (200 - 300 F) aging on the hardness of binary Ti-Cr and Ti-Mn alloys were investigated. The hardness, as quenched, of heats containing 5 to 8 percent of alloying element increased sharply with decreasing cooling rate. It was discovered that the highest hardness values were obtained in what appeared to be single-phase beta structures. The hardness was a function of alloy content and quenching rate. As a result of these observations, the hypothesis was proposed that the beta phase, in this type of alloy, is susceptible

to a hardening phenomenon involving a submicroscopic precipitation of the alpha phase. This "coherency" hardening may occur during cooling at critical rates from the alpha-beta- or beta-phase fields, as well as during artificial aging treatments.

In connection with the above work, it was found that aging occurred at relatively low temperatures in certain of the binary Ti-Cr and Ti-Mn alloys cooled at various rates from the beta field. Hardness increases up to 100 VHN resulted from aging treatments of 45 minutes at 212 F. Similar hardness increases were produced by the heating involved in mounting metallographic specimens in Bakelite. Alloys in the as-hot-rolled condition did not harden appreciably at these low temperatures.

#### Recrystallization Experiments

Beta-stabilized titanium alloys develop undesirably large grain sizes when heated in the beta-phase field either during fabrication or subsequent heat treatment. Grain refinement of such alloys by cold working and annealing is desirable from a physical property standpoint. Experiments with a series of binary Ti-Cr alloys indicated that those containing 5 percent or less of chromium could be recrystallized into a fine-grained structure by suitable thermal-mechanical treatment. However, heats containing 10 to 30 percent chromium could not be recrystallized by conventional cold rolling and annealing techniques.

#### Isothermal-Transformation Studies

A study of the isothermal transformation characteristics of three binary Ti-Cr alloys was carried out to provide basic information which has contributed to the proper understanding of the heat-treatment reactions.

Time-temperature-transformation curves were established for three binary Ti-Cr alloys containing 2.35, 4.64, and 7.54 percent chromium, respectively. The initiation of proeutectoid alpha separation was very rapid in all of the alloys. This phase was detected at transformation times of the order of 10 to 30 seconds at all temperatures investigated. The compound  $TiCr_2$  appeared in all of the alloys in about 1 hour at temperatures of 1022-1112 F (550-600 C). At 1292 F, initiation of this reaction was prolonged to very long times (more than 100 hours).  $M_s$  temperature ranges were established for the 2.35 and 4.64 percent chromium alloys at 1004-1040 F (540-560 C) and 932-968 F (500-520 C), respectively. The 7.54 percent Cr alloy did not transform to martensite. Hardnesses of isothermally transformed specimens, in general, decreased with increasing transformation temperature and with increasing time at a given temperature.

#### Welding Studies

One of the most promising alloys reported early in last year's work was a binary which contained 15 percent chromium. In the first

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attempt to weld thin sheets of this alloy, it was found that a single-pass heliarc weld could be bent in the as-welded condition over a radius of 3T. This success led to the welding of several other intermediate and high-strength alloys, all of which could be bent either in the as-welded condition or after a heat treatment. The welding studies are being continued on some of the selected alloys mentioned above.

### Extrusion Studies

The contract between Wright Field and Metal Trims, Inc., providing for extrusion studies of titanium was delayed and, therefore, extrusion ingots were not melted at Battelle until late in this contract year. The first shipment of extrusion billets, 4-7/16 inches in diameter by about 6 inches long, has been made.

TR 52-255 (Uncl)

November 1952

SUBJECT: TITANIUM RICH TITANIUM-CHROMIUM-OXYGEN TERNARY SYSTEM  
INVESTIGATOR: Chih-Chung Wang, Nicholas J. Grant and Carl F. Floe  
CONTRACT: AF 33(038)8754  
CONTRACTOR: Massachusetts Institute of Technology  
ABSTRACT: The existence of a ternary phase,  $Ti_3Cr_3O$ , has been confirmed. It has a face-centered cubic structure with a lattice constant of 13.80 Kx. This phase does not form directly from the liquid phase. The temperature range in which  $Ti_3Cr_3O$  is stable has not been determined, but it is possible that it may transform to alpha or other phases at higher temperatures.

Massachusetts Institute of Technology intends to continue independently the investigation of this system. Inquiries concerning further publications should be referred to Massachusetts Institute of Technology.

TR 52-334 (Uncl)

December 1952

SUBJECT: DEVELOPMENT OF TITANIUM-BASE ALLOYS  
INVESTIGATOR: C. H. Lorig, et al  
CONTRACT: AF 33 (038)-3736  
CONTRACTOR: Battelle Memorial Institute  
ABSTRACT: Suitable heat treatments for the high strength alloys have been developed. By varying the heat treatment it has been possible to obtain tensile strengths of 150,000 psi with an elongation of 25% in one inch. Solution treating at higher temperatures generally increases the strength but with a corresponding loss in ductility. It now seems commercially probable to solution treat, machine, and subsequently age, thus producing alloys with a high strength level.

A new phase, called omega, has been discovered by X-Ray diffraction studies. This omega phase seems to be responsible for the loss in ductility, or embrittlement which accompanies an increase in

tensile strength upon heat treatment. Results indicate that the omega phase vanishes after a certain time at elevated temperatures. Therefore, the omega phase may be a transition product from beta to alpha. The omega phase is pseudocubic in nature and localized increased concentrations of alloying elements indicate that the omega phase is lower in alloy content than the original alpha. The omega phase definitely appears to be connected with the high hardness characteristics of beta stabilized alloys.

A significant development has been the production of ductile arc welds in alpha-beta alloys; varying degrees of ductility have been obtained in alpha-beta alloys by annealing or tempering after welding.

A program has been initiated whereby industrial concerns will evaluate the newly developed alloys of titanium for large scale usage.

TR 6595, Part 1 (Uncl)

November 1951

SUBJECT: STUDIES AND EXPERIMENTAL INVESTIGATIONS FOR THE DEVELOPMENT OF PHASE DIAGRAMS OF THE TITANIUM-CHROMIUM AND TITANIUM-COPPER ALLOY SYSTEMS  
INVESTIGATOR: Frank B. Cuff, Jr., Arnold S. Joukainen, Lee S. Richardson and John C. Nicholls  
CONTRACT: AF 33(038) 8754  
CONTRACTOR: Massachusetts Institute of Technology  
ABSTRACT: The titanium-chromium binary system has been partially completed in the range from 0 to 63 percent chromium, using high purity (99.7 percent) sponge titanium and electrolytic chromium.

A preliminary diagram has been drawn of the titanium-copper system from x-ray and metallographic investigations.

An investigation is in process for determining a reliable method for analyzing the oxygen and nitrogen content of titanium by the use of vacuum fusion.

TR 6595, Part 2 (Uncl)

December 1951

SUBJECT: STUDIES AND EXPERIMENTAL INVESTIGATIONS FOR THE DEVELOPMENT OF PHASE DIAGRAMS OF THE TITANIUM-CHROMIUM AND TITANIUM-COPPER ALLOY SYSTEMS, Part 2. THE TITANIUM-COPPER AND THE TITANIUM-CHROMIUM PHASE DIAGRAMS  
INVESTIGATOR: Arnold S. Joukainen and Frank B. Cuff  
CONTRACT: AF 33(038) 8754  
CONTRACTOR: Massachusetts Institute of Technology  
ABSTRACT: In view of the recognition of the potentialities of titanium and its alloys as important structural materials, there has arisen a need

for a systematic investigation of various binary diagrams. Of these, the titanium-copper, and the titanium-chromium systems were investigated under this contract.

The titanium-copper system was found to contain four intermetallic compounds:  $Ti_2Cu$ ,  $TiCu$ ,  $Ti_2Cu_3$  and  $TiCu_3$ . It is an eutectoid type system offering heat treatment possibilities due to a suppression of the alpha to beta transformation.

The titanium-chromium system was of particular interest because of the improved properties imparted to titanium by small chromium additions. It was found that a continuous series of solid solutions existed between titanium and chromium. An intermetallic compound,  $TiCr_2$ , which decomposes upon heating, was found at 60 to 65 weight percent chromium. At the titanium end of the diagram there is an eutectoid type of reaction at 15 weight percent chromium.

TR 6596, Part 1 (Uncl)

October 1951

SUBJECT: TITANIUM-NICKEL PHASE DIAGRAM.  
INVESTIGATOR: John P. Nielsen and Harold Margolin  
CONTRACT: AF 33(038)-8725  
CONTRACTOR: New York University  
ABSTRACT: Covering the period of September 30, 1949 to December 1, 1950, this report presents the data obtained by the Research Division of New York University. The titanium-nickel phase diagram has been investigated up to 90 percent nickel, and the features up to 40 percent nickel have been established. An eutectic horizontal is found between  $950^\circ$  and  $965^\circ C$ , and an eutectoid transformation between  $750^\circ$  and  $775^\circ C$ . Little solubility of nickel in alpha titanium is indicated. Preliminary experiments on high nickel alloys indicate a possible error in the Wallbaum diagram in the range 55 - 60 percent nickel. Because of possible contamination, further work is necessary to determine whether any difference actually exists. Also included are accounts of alloy preparations, heat treatment, polishing and x-ray techniques employed in this investigation.

TR 6596, Part 2 (Uncl)

October 1951

SUBJECT: THE TITANIUM-NICKEL PHASE DIAGRAM.  
INVESTIGATOR: H. Margolin, E. Ence and J. P. Nielsen  
CONTRACT: AF 33(038)-8725  
CONTRACTOR: New York University  
ABSTRACT: This summary report presents the data obtained by the Research Division of New York University for Part 2 of the investigation of the Titanium-Nickel Phase diagram during the period 1 December 1950 to 30 September 1951.

The complete diagram from 0-100% nickel and a comparison of the phase diagrams for Process A sponge and iodide titanium-base

nickel alloys up to 15% nickel are presented. Comparisons of results have been made with other work described in the literature. Copper contamination encountered in high-nickel alloys was almost entirely eliminated by using smaller charges and shorter melting times.

Summaries of procedures for alloy preparation, melting, heat treatment, metallographic and X-ray investigation are included.

TR 6597, Part 1 (Uncl)

November 1951

SUBJECT: THE TITANIUM-IRON PHASE DIAGRAM

INVESTIGATOR: W. J. Fretague, C. S. Barker and E. A. Peretti

CONTRACT: AF 33(038) 8495

CONTRACTOR: University of Notre Dame

ABSTRACT: This project was concerned with the development of a phase diagram of the titanium-iron system, with special emphasis on that region of the diagram between 0 and 50 percent iron and from room temperature up to and including the solidus of the system. An arc melting furnace, employing a water cooled tungsten electrode and copper crucible, was constructed and operated with an argon atmosphere. Approximately seventy-seven arc melted alloys were prepared covering the composition range from 0 to 71 percent iron. Hardness data on the as cast alloys were collected and metallographic examination of all as cast alloys performed. A tentative diagram was constructed from the information obtained from metallographic examination of the arc melted alloys, and from published information appearing in the literature. The eutectic composition of the system was estimated to be at approximately 32 percent iron as determined by examination of the as cast structures. The eutectic temperature of the Process A titanium - 32 percent iron alloy was determined to be  $1094^{\circ} \pm 1^{\circ}\text{C}$ . Thermal analysis of a 10 percent iron alloy established an arrest at approximately  $550^{\circ}\text{C}$ . At the present time, this is believed to be an eutectoid reaction although typical eutectoid microstructures have not been obtained.

#### ALLOYS, NONFERROUS, VANADIUM

TR 52-145 (Uncl)

May 1953

SUBJECT: EXPLORATION OF VANADIUM BASE ALLOYS

INVESTIGATOR: W. Rostoker, D. J. McPherson and M. Hansen

CONTRACT: AF 33(038)-8517

CONTRACTOR: Armour Research Foundation, Illinois Institute of Technology

ABSTRACT: This is an annual report summarizing the results of work directed toward the development of vanadium-base alloys accomplished during the period May 8, 1951 to May 8, 1952. The alloying characteristics of vanadium with twenty-one solute elements were studied in sufficient detail to provide information on solubility limits, first intermediate phases and reaction between the solid solution and the first intermediate phase. The development of hot forging, annealing, scalping and rolling practices has been pursued. A large number of alloys have been successfully forged.

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The oxidation characteristics of vanadium alloys have been examined. It has been demonstrated that oxidation behavior is primarily controlled by the presence or absence of molten  $V_2O_5$ . Several alloy additions appear to raise the melting point of this oxide.

#### ANALYSIS AND MEASUREMENT

TR 53-32 (Uncl)

February 1953

SUBJECT: THE CATALYTIC OXIDATION OF AMMONIA, AN EXPERIMENTAL STUDY.  
INVESTIGATOR: Hyman Marcus  
ABSTRACT: An investigation was conducted to determine the feasibility of removing ammonia gas (injected by necessity) from an air conditioning system by the catalytic action of promoted and unpromoted cupric oxide and a cobalt-bismuth oxide mixture.

A system was designed to deliver 0.378 pounds per minute of a 5% ammonia-enriched air mixture to the catalyst for conversion. This laboratory model was scaled down by a factor of one hundred so that the facilities of the laboratory could best be utilized. The materials used to promote the action of the cupric oxide included red iron oxide, green nickel oxide, and a mixture of the two. The cobalt-bismuth mixture was prepared from the respective nitrates and was analyzed to contain 3% bismuth oxide and 97% cobaltous oxide. Analyses of the inlet and exit gases were accomplished to maintain the former at not less than 5% enrichment and to determine the nature of the reaction products at the exit.

The conversion reaction proceeded when the temperature of the preheated gas mixture passing over the catalyst bed had reached approximately 800° F. The temperature of the catalyst bed was raised to about 1500° F and higher due to the exothermic nature of the reaction. The energy released in the oxidation of ammonia is of the order of 215 kilocalories per mole. The reaction products consisted of a mixture of nitric oxide, nitrogen dioxide, nitrogen, water vapor, and the ammonium salts of nitrous and nitric acids.

TR 53-44 (Uncl)

March 1953

SUBJECT: ELECTRON MICROSCOPE AND ELECTRON DIFFRACTION STUDY OF OPTICALLY CONDUCTING COATINGS ON GLASS AND ACRYLIC PLASTIC.  
INVESTIGATOR: Stanley A. Szawlewicz  
ABSTRACT: Electron microscopy and electron diffraction were used to determine the microstructure of several types of commercially produced transparent conducting coatings on glass. This work was conducted as part of a program to evaluate various conducting coatings intended for use



on aircraft windshields in preventing fog, frost, or ice and to aid in the development of conducting coatings which could be applied to transparent aircraft canopies for the purpose of dissipating precipitation static charges.

Several experimental transparent conducting coatings produced under Air Force contract were also studied. This included the study of the latest development in the preparation of a conducting coating for acrylic plastic canopies which consists essentially of the mechanical application of fine graphite to the plastic surface.

TR 53-112 (Uncl)

April 1953

SUBJECT: DEVELOPMENT OF GLASS COLOR STANDARDS.  
INVESTIGATOR: H. C. Hellige  
CONTRACT: AF 33(600)-6395  
CONTRACTOR: Hellige, Inc.  
ABSTRACT: The development of glass color standards to be used as visual comparison standards in adjusting the concentration of four dye additives in aircraft fuels is discussed. A practical and satisfactory color comparison vessel which would permit easy differentiation between maximum and minimum allowable colors of each of four dye colors was selected. A reproducible source of illumination for comparison of the glass standards to the dyed fuels was determined. A master set of glass standards exactly matching fresh fuel samples was made. A few months later a second set of glass standards was completed on the basis of the master set; however, after this time the contractor's set of fuels had changed color slightly, and counter samples retained by the Air Force had changed greatly. No positive mathematical relationship can be applied to comparing the glass color standards to the original spectrophotometric curves of the dyed fuels due to differences in viewing depth, the effect of a discrimination increasing color filter, and differences in illumination. It is concluded, however, that on the basis of visual comparison, the color standards are satisfactory for the intended purpose.

TR 52-168 (Uncl)

July 1952

SUBJECT: THE INFLUENCE OF EXTRANEEOUS ELEMENTS IN D. C. ARC SPECTRA OF FERROUS ALLOYS.  
INVESTIGATOR: Darwin P. Jensen and J. F. Young  
CONTRACT: AF 33(038)-23304  
CONTRACTOR: Douglas Aircraft Company, Inc.  
ABSTRACT: The influence of one alloying element upon the spectral line intensity of any other alloying element was subjected to investigation in the D. C. Arc. The study was carried out by making homogeneous metallic alloys in an induction furnace. Manganese, silicon, nickel, chromium, molybdenum, vanadium, aluminum and copper were used as the alloying elements in an iron matrix, with percentage magnitudes commonly found in low alloy steels. It is concluded that;

(1) The only influence which could be attributed to any

of these elements was that of copper upon the line intensity of manganese.

(2) Oxygen contained within the metallic sample has a marked influence on the spectral line intensity of chromium.

(3) Some other element or elements not included in this investigation such as carbon, sulfur and/or phosphorus affects the line intensities of nickel, silicon and manganese.

(4) Alloys can be melted in an induction furnace without change in chemistry by employing the proper techniques.

TR 52-246 (Uncl)

November 1952

SUBJECT: DEVELOPMENT OF COMPOSITE SPECTROPHOTOMETRIC PROCEDURES FOR THE ANALYSIS OF LOW-ALLOY STEELS AND OF ALUMINUM AND ITS ALLOYS.

INVESTIGATOR: Stanley H. Simonsen and Gilbert H. Ayres

CONTRACT: AF 33(038)-23168

CONTRACTOR: University of Texas

ABSTRACT: Procedures have been developed for the spectrophotometric analysis of the constituents of low-alloy steels and of aluminum and its alloys, using a single sample to give a composite solution in which most of the elements are determined. In general, the conventional spectrophotometric methods for the various elements have been employed, modified as necessary for the use of the single composite solution technique. The methods have been tested thoroughly, in the hands of several different operators, by applying them to a variety of standard samples; the results of these tests are tabulated in the report.

Detailed procedures, with explanatory notes, to serve as a practical laboratory manual are given for the spectrophotometric analysis of low-alloy steels for chromium, copper, manganese, molybdenum, nickel, phosphorus, silicon, and vanadium, and for the analysis of aluminum and its alloys for chromium, copper, iron, manganese, molybdenum, nickel, titanium, and vanadium. The molybdisilicic acid method for silicon in the aluminum samples did not give satisfactory results; the conventional gravimetric method for this determination is recommended.

TR 52-282 (Uncl)

October 1952

SUBJECT: THE PURKINJE EFFECT IN LUMINANCE MEASUREMENTS OF AIR FORCE PHOSPHORS.

INVESTIGATOR: Daniel I. Pomerantz and John R. Cannon

ABSTRACT: A formula is derived for relating effective and photopic units of luminance, making use of Weaver's interpolated data for the mesopic luminosity functions. This formula is applied to the spectra of

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four typical Air Force luminescent phosphors and the calculated results are compared with experimental data obtained at Wright Air Development Center. It is concluded that Weaver's data may tentatively be accepted for conversion between effective and photopic units in luminance measurements of luminescent materials.

TR 6520 (Uncl)

November 1951

SUBJECT: AN EVALUATION OF X-RAY METHODS FOR THE QUANTITATIVE DETERMINATION OF TETRAETHYLLEAD IN AVIATION GASOLINE.  
INVESTIGATOR: Jack T. Humphries  
ABSTRACT: A brief description of the x-ray absorption and fluorescence methods for the determination of tetraethyllead is given. Samples of aviation gasoline, Specification MIL-F-5572, were tested with each method and the results are included in the report. These results indicate that the fluorescence method is applicable to the need of the Air Force for a rapid, accurate analysis. The absorption method does not give the desired accuracy.

The methods of sample preparation and the arrangement of equipment are described.

It is found that an x-ray fluorescence analysis for tetraethyllead content requires approximately eight minutes, a feature which makes the x-ray analysis much more desirable than the usual chemical method.

#### BIOCHEMISTRY

TR 52-214 (Uncl)

November 1952

SUBJECT: CHEMICAL INVESTIGATION OF FLUORINE COMPOUNDS AS FUNGICIDES.  
INVESTIGATOR: G. C. Finger, F. H. Reed, and J. E. Dunbar  
CONTRACT: AF 33(038)-26990  
CONTRACTOR: Illinois State Geological Survey  
ABSTRACT: The chemical research program on organic fluorine compounds in reference to new fungicides was resolved into two phases - (1) the synthesis of compound types for rapid screening, and (2) a detailed study of the most promising types of compounds.

Approximately 35 fluorinated compounds belonging to the quinone, hydroquinone, phenol, aniline, and nitrobenzene types were synthesized and furnished the fungicidal testing program. The method of synthesis and the properties of each compound are described briefly. More than half of the compounds described are new and their chemical structures definitely proven. In several instances, 100-g. samples were

prepared of the most promising compounds.

All of the compounds submitted for screening showed fungicidal properties with the dinitro and nitrophenols showing most promise. The greatest potency was discovered with 1-fluoro-3-bromo-4,6-dinitrobenzene as it prevented fungus growth at 0.8 ppm. Complete protection of cotton thread and no loss of tensile strength were obtained by impregnation with the compound.

Reported for the first time is the synthesis of a chloro-fluoroquinone by the 1,4 addition of hydrogen chloride to a fluoroquinone followed by oxidation with hydrogen peroxide.

TR 6518, Part 1 (Uncl)

August 1952

SUBJECT: FUNGISTATIC CAPACITIES OF AROMATIC FLUORINE COMPOUNDS IN RELATION TO CLOTH-ROTTING FUNGI. PART 1 - FLUORINATED QUINONES AND PHENOLS.

INVESTIGATOR: Leo R. Tehon and Sylvia Wolcyrz

CONTRACT: AF 33(038)-10897

CONTRACTOR: Illinois State Natural History Survey

ABSTRACT: Examination of aromatic fluorine compounds--six quinones and three phenol isomers--by dilution plate and cloth square methods with respect to four cloth-deteriorating fungi showed general possession of fungistatic properties. All the quinones and two of the phenol isomers exhibited appreciable fungistatic capacities. The compound 2,5-difluoro-1,4-benzoquinone was most potent, completely inhibiting growth of Chaetomium globosum on unfavorable and favorable media at concentrations of 62 and 375 milligrams per liter, respectively, and completely protecting through 14 days squares of duck cloth saturated with an aqueous dispersion of the compound containing 500 milligrams per liter. Among the quinones fungistatic potency appeared to vary both with fluorine content--the higher the content, the more potent the compound--and, independently of fluorine content, with molecular structure. With phenol isomers, the position of the fluorine atom strongly influenced potency.

TR 6518, Part 2 (Uncl)

August 1952

SUBJECT: FUNGISTATIC CAPACITIES OF AROMATIC FLUORINE COMPOUNDS IN RELATION TO CLOTH-ROTTING FUNGI. PART 2 - FLUORINATED PHENOLS, NITROBENZENES, AND ANILINES.

INVESTIGATOR: Leo R. Tehon and Sylvia Wolcyrz

CONTRACT: AF 33(038)-10897

CONTRACTOR: Illinois State Natural History Survey

ABSTRACT: Of the twenty-five compounds tested since 1 March 1951, nine are phenols, nine are nitrobenzenes, four are anilines and three are other fluorinated preparations. Among the compounds and included for comparison are five that do not contain fluorine but are similar in structure to those that do.

To determine fungistatic potency, three test methods were employed; the agar dilution plate method, a treatment of squares of cotton fabric, and a treatment of cotton thread. Only those compounds that showed high toxicity by the first procedure were given the second and third tests. With the agar dilution plate method four fungi were used. With the other methods only the fungus Myrothecium verrucaria was used.

All of the compounds inhibited development of the fungi in some degree. Effective concentrations in agar were generally above 500 mg/liter for the phenols, above 200 mg/liter for both the anilines and the two nitrobenzenes, and above 5 mg/liter for the seven dinitrobenzenes.

Of the dinitrobenzenes, the most effective was 1-fluoro-3-bromo-4,6-dinitrobenzene. It prevented the four test fungi from developing on agar that contained as little of it as 0.8 mg/liter and completely protected impregnated cotton thread that by weight contained only 0.15% of it.

### CERAMICS

TR 53-9 (Uncl)

January 1953

SUBJECT: REFRACTORY MATERIALS FOR USE IN HIGH-TEMPERATURE AREAS OF AIRCRAFT.  
INVESTIGATOR: Norman R. Thielke  
CONTRACT: W33-038-ac-16374  
CONTRACTOR: Pennsylvania State College  
ABSTRACT: Theoretical approaches to the mechanism of thermal expansion were reviewed and applications thereof to the alkali halides were examined for clues to the thermal behavior of refractory materials. Inadequate theory and incomplete data precluded any valid generalizations. Crystal structure appeared as an important determiner of expansion behavior.

Aluminum titanate bodies matured only above 1260°C; five hours' heating at 1400°C developed moderate strength and low expansivity. Expansion of such bodies to 1000°C approached zero; a rapid rise accompanying decomposition ensued between 1000° and 1400°C. Thermal hysteresis was indicated as a time-consuming effect related to reaction equilibrium. The isostructural nature of aluminum titanate and pseudo-brookite was confirmed and the expansion anisotropy of the former was investigated. Substitution of equivalent or isomorphous oxides in the aluminum titanate formula yielded no marked improvement in overall properties. Addition of numerous high-silica glasses also failed to strengthen the bond of aluminum titanate bodies without sacrifice of low expansivity.

Slip-cast, clay-bonded alumina and beryl turbine nozzle

blades failed after 1-4 cycles of thermal shock; similar clay-bonded aluminum titanate blades easily withstood 75 cycles of shock from 885° to 25°C under simulated service conditions.

A literature review relative to crystallographic inversions indicated the merit of solid soluble constituents or a restraining glassy envelope as means of control of damaging volume changes during thermal cycles.

TR 53-165 (Uncl)

June 1953

SUBJECT: ALUMINUM TITANATE AND RELATED COMPOUNDS.  
INVESTIGATOR: Norman R. Thielke  
CONTRACT: AF 33(616)-139  
CONTRACTOR: Pennsylvania State College  
ABSTRACT: The preparation of aluminum titanate and its structural, thermal and mechanical properties were investigated. A melting temperature of 1865°C and a region of instability between 1260°C and about 860°C, plus extreme thermal expansion anisotropy in the crystal rise to unusual properties in the matured crystalline aggregate. These include negative expansion coefficients, marked resistance to thermal shock, thermal expansion hysteresis and low transverse strength. The expansion behavior and strength of matured aggregates are variously altered by heat treatment, by kiln atmosphere and by incorporation of minor amounts of oxides or glasses.

Aluminum titanate is recommended as a thermal shock resistant refractory material in applications involving low tensile loads and oxidizing conditions at temperatures within its stability ranges. Fabricated shapes may serve satisfactorily as nozzle diaphragm blades, flame tube liners, refractory coatings or other ceramic elements of combustion systems.

TR 52-67 (Uncl)

March 1952

SUBJECT: MECHANICAL PROPERTY TESTS ON CERAMIC BODIES.  
INVESTIGATOR: W. H. Duckworth, A. D. Schwoppe, and O. K. Salmassy  
CONTRACT: AF 33(038)-8682  
CONTRACTOR: Battelle Memorial Institute  
ABSTRACT: A critical survey was made of the significant theories of strength, for guidance in developing relationships among the strength properties of ceramics. The mechanistic theories appeared to offer the greater possibilities, but no theory treated all controlling variables, and all theories lacked adequate experimental support. The need remains apparent for a unified theory and supporting experimental data.

The principal laboratory effort was on the size dependence of strength. Both plaster and a nickel-titanium carbide body decreased in apparent strength with increases in gage-section size in bend

tests. In an extensive program of bend tests on plaster to record details, strength decreased with increases in either gage-section length or gage-section breadth in about the same manner. However, the apparent strength increased with increases in gage-section depth. The possibility of the true size effect's being masked by size-dependent testing variables was indicated. There was no trend apparent in the standard deviation of strength values with variations of gage-section length, breadth, or depth.

Further information was obtained on the effect of the type of test on mechanical properties. Of particular interest is the fact that, with sufficient refinement, the bend and torsion tests appear to yield practically the same strength values. The development and refinement of tests was continued in an effort to obtain the precise mechanical-property data needed in this program.

TR 52-92 (Uncl)

April 1952

SUBJECT: INVESTIGATION OF INFILTRATED AND SINTERED TITANIUM CARBIDE.  
INVESTIGATOR: C. G. Goetzl, J. B. Adamec, J. L. Ellis, and D. Trauberman  
CONTRACT: AF 33(038)-16103  
CONTRACTOR: Sintercast Corporation of America  
ABSTRACT: An investigation was carried out for the purpose of evaluating composite bodies consisting of titanium carbide and nickel-base alloys and intermetallic compounds, produced by the infiltration and conventional powder metallurgical processes for use as structural materials in high-temperature components of aircraft engines.

The nickel alloys and the one compound tested were Ni-chrome V, Hastelloy "C", Inconel, and NiAl, respectively. Production techniques were developed for nine in. long stress rupture test bars, containing Inconel as infiltrant. These were produced by the infiltration process and submitted to the Materials Laboratory, Research Division, Wright Air Development Center for stress rupture tests together with specimens of similar composition made by sintering.

Tests carried out on the material were:

1. oxidation testing in air at 1600°, 1800°, and 2000°F;
2. X-ray diffraction analysis of the oxide products;
3. thermal shock testing at 2500° and 2300°F;
4. modulus of transverse rupture at room temperature;
5. modulus of transverse rupture at 1800°F;
6. ductility at 1800°F.

It was found that, among the materials tested, titanium carbide-Inconel, infiltrated by the capillary infiltration method, had the

most favorable combination of high-temperature strength, ductility, and oxidation resistance at elevated temperatures. Its facility of production, however, was inferior to that of titanium carbide infiltrated with other nickel alloys. While it was possible to produce from Inconel-infiltrated titanium carbide  $3 \times 1/2 \times 1/2$  in. specimens of great physical and structural uniformity, nine in. long bars required for stress rupture specimens still possessed some regions of less homogeneity as evidenced by microporosity.

In the modulus of transverse rupture tests, the Inconel-infiltrated type of material proved to be far superior in strength at room temperature, strength at  $1800^{\circ}\text{F}$ , and bending capacity at  $1800^{\circ}\text{F}$ , over a cemented titanium carbide of similar composition made by cold-pressing and sintering.

TR 52-291 (Uncl)

September 1952

SUBJECT: AN INVESTIGATION OF VARIOUS PROPERTIES OF NiAl.  
INVESTIGATOR: Richard L. Wachtell  
CONTRACT: AF 33(038)-10716  
CONTRACTOR: American Electro Metal Corporation  
ABSTRACT: Production of the alloy NiAl and a modified composition NiAl + 5% Ni has proved feasible as well as its subsequent fabrication by powder metallurgical technique. Properly hot-pressed bars of the NiAl + 5% Ni composition show strengths in modulus of rupture as high as 144,000 psi at room temperature and 68,000 at  $980^{\circ}\text{C}$ .

The air oxidation resistance of the modified NiAl + 5% Ni composition is excellent up to  $1095^{\circ}\text{C}$ ., with weight gains of the order of 1.25 MG./CM<sup>2</sup> being exhibited after 300 hours of exposure.

Heat shock properties are likewise excellent, as judged by NACA tests, and by performance in the Air Force Heat Shock apparatus.

TR 6601, Part 2 (Uncl)

October 1952

SUBJECT: AN INVESTIGATION OF THE ALLOYS OF ALUMINUM AND MOLYBDENUM.  
INVESTIGATOR: Richard L. Wachtell  
CONTRACT: AF 33(038)-10716  
CONTRACTOR: American Electro Metal Corporation  
ABSTRACT: In addition to the conclusions cited in the previous report (Air Force Technical Report 6601, Part 1), the following significant facts have been established from the work which is reported herein;

(1) No firm explanation has been established regarding the mechanism of rapid oxidation of certain of the Molybdenum Aluminum alloys, but its existence under conditions of good ventilation suggest a mechanism different from that of the usual "catastrophic oxidation" of Mo containing alloys.



(2) Oxidation resistance data have been obtained for several alloys, and it is shown that a properly chosen Mo/Al alloy, specifically, the No. 2 alloy + 10% Al, or No. 2 + 15% Al, as described in the text, will develop excellent oxidation resistance in all temperature ranges tested (870°C to 1150°C).

(3) Hot pressing of shapes of these alloys is extremely difficult due to the sticking tendencies of the material, but three representative parts have been made; a rocket nozzle, a turbosupercharger bucket, and stress to rupture bar.

(4) Control equipment has been developed for the hot pressing operation which makes possible a fair reproducibility of strength in small bars of 40,000-50,000 PSI (modulus of rupture).

(5) A pre-alloyed powder of the same overall chemical analysis as the No. 2 alloy + 10% Al has about the same oxidation resistance, but is more difficult to hot press.

(6) Methods have been developed for the relatively large scale production (1 kg batches) of Mo/Al powder.

(7) Metallographic studies indicate that the physical properties of the alloys under investigation may be influenced by heat treatment.

#### CLEANING

TR 52-100 (Uncl)

August 1952

SUBJECT: IMPROVEMENT OF JET ENGINE DESCALING PROCEDURE.  
INVESTIGATOR: G. M. Bryan  
CONTRACT: AF 33(038)-23310  
CONTRACTOR: Northrop Aircraft, Inc.  
ABSTRACT: X-ray diffraction analysis of the Inconel scale on combustion tube inner liners revealed that it is composed of nickel oxide, the major component, and lesser amounts of chromium oxide and iron oxide. Metallographic examination demonstrated that heavy scale is associated with precipitation, possibly carbides at the grain boundaries, a fact which can explain intergranular corrosion of scaled Inconel in acid solutions.

Inconel scale could not be taken off in neutral or alkaline solvents but several acid solutions were found which remove most of the scale without seriously attacking the base metal. Oxidizing pretreatments, particularly with the alkaline permanganate solution in current use by the Air Force, were shown to promote efficient acid pickling.

Physical tests of Inconel specimens descaled with the nitric acid-ferric chloride solution revealed that high temperature pickling (160°F) caused a severe loss in tensile strength whereas room temperature pickling caused no appreciable loss in tensile strength.

A full scale test of the nitric acid-ferric chloride solution was performed at Norton Air Force Base, San Bernardino, and satisfactory results were achieved.

#### COATINGS

TR 52-36 (Uncl)

March 1952

SUBJECT: DEVELOPMENT OF TRANSPARENT MATERIALS WHICH REDUCE EFFECTS OF PRECIPITATION STATIC IN AIRCRAFT.  
INVESTIGATOR: M. U. Cohen, PhD and G. A. Dalin, PhD  
CONTRACT: AF 33(038)-12240  
CONTRACTOR: Balco Research Laboratories  
ABSTRACT: Methods of laying a transparent electrically conductive film on plastic airplane canopies are discussed. The purpose of such films is to conduct to the aircraft frame the static charges developed on the canopies by friction with air, dust, snow, etc., during flight. Unless these charges are properly dissipated, precipitation static results, producing serious interference with radio communication.

The types of film studied include metal oxides, metals, phosphors, polyelectrolytes, electrolytes dispersed in waxes, and electrolytes dispersed in non-polar polymers.

Special techniques employed in the research include film-forming by withdrawing slides from solution at a controlled rate, vacuum-evaporation of metals, metallic oxides and phosphors, a convenient method of measuring surface resistance, and the deposition from solution of adherent metal-oxide films on acrylic sheet.

Preliminary studies indicate that the monobutyl ester of orthophosphoric acid in polymethyl methacrylate and analogous systems merit further detailed investigation.

TR 52-48 (Uncl)

December 1952

SUBJECT: DEVELOPMENT OF ELECTRICALLY CONDUCTIVE TRANSPARENT COATINGS FOR ACRYLIC PLASTIC.  
INVESTIGATOR: Johan Bjorksten, Harry L. Hamilton, and Evelyn E. Smith  
CONTRACT: AF 33(038)-23319

CONTRACTOR: Bjorksten Research Laboratories, Inc.  
ABSTRACT: In order to dissipate precipitation electrostatic charges built up on transparent plastic aircraft canopies during flight an electrically conductive transparent coating, easily applied to formed aircraft canopies made from acrylic sheet conforming to Specification MIL-P-5425, has been developed. The coating is applied by abrading or scratching the acrylic surface slightly with a suede brush, rubbing in finely divided graphite, and spraying the surface with a protective film of 1:5 methacrylic acid-methyl methacrylate copolymer resin.

The composite material, i. e., the acrylic and applied coating, retains essentially all the original mechanical properties, optical clarity and light transmittance characteristics of the base material. Its surface resistance is in the range 1-10 megohms per square and is relatively insensitive to the wide variation in relative humidity, temperature, and altitude conditions that might be expected in aircraft operation. The coated acrylic is transparent to radio frequency energy as well as light, its dielectric loss factor being only slightly higher than the acrylic alone. It has sufficient permanence to the effects of sunlight, temperature variations, crazing, rain, abrasion, wind erosion, and oil absorption associated with the normal operation and maintenance of aircraft.

Three F-86 aircraft canopies, two new and one removed from service, were coated with the developed coating. The new canopies were tested in flight at Wright Air Development Center and performed satisfactorily. Thus, the coating can be applied to newly produced canopies with the least disruption in current manufacturing practices. The used canopy crazed severely when the protective coating was applied. This was caused by the strains present in the surface. Work with small methacrylate samples similarly strained revealed that the crazing could be avoided by annealing prior to spraying. Thus, it seems likely that the developed coating can be applied to canopies removed from service after an annealing pretreatment.

TR 52-99 (Uncl)

November 1952

SUBJECT: RESEARCH INVESTIGATION OF PROTECTIVE COATINGS FOR MAGNESIUM.  
INVESTIGATOR: H. D. Childers, K. B. Niles, and A. G. Valles  
CONTRACT: AF 33(038)-23273  
CONTRACTOR: Northrop Aircraft, Inc.  
ABSTRACT: Numerous proprietary and developmental organic coatings are screened for relative corrosion protection of magnesium sheet alloy, with respect to a current Government specification system. Superior primers and systems are more fully evaluated for mechanical properties as well as corrosion protection. It was found that air-dry vinyl systems offer optimum protection, considering the systems tested. Developmental data and discussions of magnesium corrosion inhibitors and galvanic cell test methods

are included in the report.

### CORROSION

TR 53-16 (Uncl)

February 1953

SUBJECT: CORROSION PREVENTIVE ADDITIVES  
INVESTIGATOR: E. J. Schwoegler and L. U. Berman  
CONTRACT: AF 33(038)-9202  
CONTRACTOR: Armour Research Foundation of Illinois Institute of Technology  
ABSTRACT: This project was undertaken with the object of developing new corrosion inhibitors to supplement or replace petroleum sulfonates. A study of petroleum sulfonates was made to determine the nature of the compounds showing corrosion inhibition. Separation of a commercial sodium petroleum sulfonate into certain components was effected by chromatography. Both Attapulugus clay and paper were successful in fractionating the petroleum sulfonates so that physical measurements could be made on the fractions. From these studies, it appears that sodium petroleum sulfonates are alkyl benzene derivatives with the alkyl group in the para position to the sulfonic acid group.

A large number of commercially available organic compounds were evaluated by the NRL Static Water Drop Test and by the use of a galvanic couple system at 95 per cent Relative Humidity at 100°F. Several good inhibitors were found by the Static Water Drop Test method. The test presently used, employing the galvanic couple, is not as efficient for screening as the Static Drop Test method. In spite of this, certain general information concerning the type of organic compounds, which will inhibit galvanic corrosion with the system used, has been obtained. Guided by data obtained from these evaluation tests, information obtained from the chromatography and information gained from experience in the field, a large number of organic compounds were synthesized having corrosion inhibiting properties. These included glyoxalidines, alkyl aryl sodium sulfonates, amine salts of 2-ethylhexoic, oleic, nicotinic, pelargonic, linoleic, and dodecylbenzene-sulfonic acids.

TR 6519, Part 1 (Uncl)

March 1952

SUBJECT: MATERIALS FOR HANDLING FUMING NITRIC ACID.  
INVESTIGATOR: Frank H. Beck, M. L. Holzworth, and Mars G. Fontana  
CONTRACT: AF 33(038)-10381  
CONTRACTOR: Ohio State University Research Foundation  
ABSTRACT: Welded drums of Type 347 stainless steel fail by "knife-line" attack if the heat effected zone (destabilized zone) is subjected to a sensitizing treatment (900° to 1500°F) after welding. Failure by

knife line attack occurs because the columbium carbide in a narrow zone adjacent to the weld goes into solution and remains in solution on subsequent cooling (this effect is called destabilization). Sensitizing treatments cause the precipitation of chromium carbide in the grain boundaries (as is observed in Type 304 stainless steel) and intergranular corrosion results. Failure by knife-line attack has not been observed in Extra Low Carbon Type 347 stainless steel. Type 347 stainless steel is not susceptible to stress corrosion by fuming nitric acid at 160°F.

The high corrosion rates which occur on Type 347 stainless steel in fuming nitric acid at 160°F can be reduced from 100-200 mils per year to approximately 13 mils per year by the addition of aluminum nitrate or aluminum metal to the acid solution in concentrations of approximately 0.1% aluminum or higher.

Titanium, Haynes alloy "25" (L-605) and zirconium show excellent resistance to fuming nitric acid in the temperature range, room temperature to 160°F.

Aluminum and some of its alloys show better corrosion resistance than the stainless steels at 160°F.

Investigation of the properties, such as decomposition characteristics, of fuming nitric acid was begun.

TR 6519, Part 2 (Uncl)

November 1952

SUBJECT: MATERIALS FOR HANDLING FUMING NITRIC ACID. PART 2 - PROPERTIES OF FUMING NITRIC ACID WITH REFERENCE TO ITS THERMAL STABILITY.

INVESTIGATOR: Mars G. Fontana

CONTRACT: AF 33(038)-10381

CONTRACTOR: Ohio State University Research Foundation

ABSTRACT: Corrosion tests were conducted on several metals and alloys in white and red fuming nitric acids at room temperature, 122°, and 160°F. Titanium, titanium base alloys Ti-150A and RC-130-B, zirconium, and Haynes 25 alloy (L-605) were found very resistant to fuming nitric acid at all temperatures tested. Aluminum and some of its alloys show very good corrosion resistance to FNA. Durimet-20 has fair resistance to FNA at 160°F. Stainless steels in the AISI three and four hundred series lose their corrosion resistance to FNA when the testing temperature is increased to 160°F. The nature and mechanism of knife-line attack is discussed in detail. Results of stress corrosion of Type 347 stainless steel, effect of additives to WFNA, and galvanic couple systems are reported.

The preparation of pure nitric acid and the apparatus and experimental procedure for measuring the rate of decomposition and equili-

brium decomposition pressure of nitric acid are described. During the measurements the nitric acid is confined over an inert fluorinated hydrocarbon oil in a glass tube. Pressures developed by the decomposition products of nitric acid can be measured accurately from near atmospheric pressure to 2000 psi, over a wide range of temperatures and V/L ratios. Some results of tests carried out at 167°F to check the performance of the apparatus are given which show the general relations between the decomposition pressure, composition and V/L ratio.

TR 6591 (Uncl)

July 1952

SUBJECT: CORROSION PREVENTIVE ADDITIVES.  
INVESTIGATOR: M. Feinleib and H. T. Francis  
CONTRACT: AF 33(038)-9202  
CONTRACTOR: Armour Research Foundation of Illinois Institute of Technology  
ABSTRACT: A reproducible test for ball bearing corrosion in instrument oils has been developed. Test conditions, including brass-to-52100 steel coupling, simulate field conditions, and correlation with service performance has been good.

Commercial petroleum sulfonates, which are commonly used as inhibitors in instrument oils, may be separated into fractions, some of which are corrosive while others are not. Attempts to characterize these fractions are under way.

#### CRITERIA, DESIGN

TR 53-7 (Uncl)

June 1953

SUBJECT: POISSON'S RATIO OF AIRCRAFT SHEET MATERIALS FOR LARGE STRAINS.  
INVESTIGATOR: Stanley Goodman and Stanton B. Russell  
CONTRACT: P. O. (33-038)-51-4061  
CONTRACTOR: National Bureau of Standards U. S. Department of Commerce  
ABSTRACT: Tests were conducted to determine the value of Poisson's ratio in the plane of the sheet for six aircraft sheet materials under tensile load through an axial stress range from zero to a stress producing either severe necking or fracture. Specimens were loaded at various orientations relative to the direction of rolling of the sheet.

Maximum values of Poisson's ratio obtained were: 0.434 for XA78S-T6 alclad aluminum alloy; 0.473 for 75S-T6 alclad aluminum alloy; 0.445 for 24S-T3 alclad aluminum alloy; 0.622 for FS-1h magnesium alloy; 0.769 for commercially pure titanium; and 0.544 for RC-130-A titanium alloy.

Density determinations were made of unstrained and highly strained portions of sheet. Poisson's ratio in the thickness direction was measured over a range of large axial strains for two of the materials. It was markedly different from Poisson's ratio in the transverse direction. Values of Poisson's ratio in the transverse direction computed from the measured values in the thickness direction were in good agreement with measured values in the transverse direction.

The results obtained in this investigation are compared with the results of earlier investigations conducted by the National Bureau of Standards.

TR 53-10 (Unc1)

February 1953

SUBJECT: THE INFLUENCE OF TEMPERATURE AND RATE OF STRAIN ON THE PROPERTIES OF METALS IN TORSION.

INVESTIGATOR: C. E. Work and T. J. Dolan

CONTRACT: AF 33(038)-21587

CONTRACTOR: University of Illinois

ABSTRACT: An experimental study was made to determine the effect of temperature and rate of strain on the strength, ductility and energy absorbing capacity of seven different structural metals in torsion. Cylindrical specimens 0.25 in. in diameter were tested at four different constant strain-rates from 0.0001 in./in./sec. to 12.5 in./in./sec. and at four different temperatures from room temperature up to 1200F. Two series of tests were conducted: (A) specimens were held at the test temperature for one-half hour before loading, and (B) specimens were given a two-hundred hour aging treatment at the test temperature before testing.

Torque, angle of twist, and time were continuously recorded and the torsional properties determined. The detailed results are presented in three-dimensional charts and analyzed in terms of the mechanisms altering the material behavior. In general, it was found that an increase in strain-rate caused an increase in strength, whereas an increase in temperature reduced the strength of all metals except in the blue-brittle temperature range for steel. Extremely great ductility was exhibited by some of the metals at the highest elevated temperatures employed, particularly at the slower rates of straining. The two-hundred hour aging treatment had no appreciable effect on the properties of most of the metals tested; significant changes were produced only in the aluminum alloys at 400F and 600F and in alloy steel at 1200F.

The experimental observations were compared with several theories that have been proposed to express mathematically the effects of strain-rate and temperature on mechanical properties. By proper selection of empirical constants, several equations involving a general relation for flow stress or new parameters of a "temperature-modified" strain-rate or

a "velocity-modified" temperature were found to express approximately the variations obtained in mechanical properties.

TR 52-89, Part 2 (Uncl)

August 1952

SUBJECT: PLASTIC BEHAVIOR OF ENGINEERING MATERIALS. PART 2 - PARTIALLY PLASTIC THICK-WALLED CYLINDERS.  
INVESTIGATOR: M. C. Steele  
CONTRACT: AF 33(038)-15677  
CONTRACTOR: University of Illinois  
ABSTRACT: This report presents experimental and theoretical work on the overstraining of thick-walled cylinders. Four mild steel cylinders (2:1 wall ratio) were subjected to internal fluid pressure and strains at the bore and the outside surfaces were measured. In addition, the mechanism of flow was studied by polishing the end and outside surfaces for the observation of Lueders lines. A theoretical analysis is given which is based on results from a quantitative comparison of certain previous theories and available experimental data. The solution is in closed form and is applicable to strain-hardening materials.

Observations disagree with theoretical assumptions concerning the progression of yielding; wedge regions of overstrained material, occupying a small fraction of the total volume, characterize the yielding process. Discrepancies with theory are observed in the measured strains; fully plastic load-carrying capacities predicted from theory are higher than those observed in the experiments. Instability of deformation (creep) under maintained constant load is discussed.

It is concluded that theoretical analyses, in their present form, do not cope adequately with the inelastic problem concerning the wedge type of yielding in two and three dimensional, non uniform stress fields. Suggestions are given for further research.

TR 52-252 (Uncl)

December 1952

SUBJECT: DYNAMIC TESTING OF MATERIALS AND STRUCTURES WITH A NEW RESONANCE-VIBRATION EXCITER AND CONTROLLER.  
INVESTIGATOR: B. Lazan, A. Gannett, and P. Kirmser  
CONTRACT: AF 33(038)-18903  
CONTRACTOR: University of Minnesota and Syracuse University  
ABSTRACT: The nature of near-resonance vibration and response characteristics are discussed to clarify the relationships among resonance amplification factor, damping energy and dynamic modulus of elasticity. A newly developed machine is described for exciting and controlling resonance or near resonance vibrations in materials and joints under various types of stress. This machine imposes in adjustable-while-running mechanical exciting force at a controllable fre-



quency and by means of automatic electronic controls maintains (a) the desired vibration phase angle (usually  $90^\circ$  for resonance) by controlling the frequency of the exciting force, and (b) the desired magnitude of the excited force by automatically controlling the magnitude of the exciting force. Equations are developed for determining the resonance amplification and other properties from the machine readings. The stability and accuracy of the machine are discussed. Data are presented on the damping and elasticity properties of aluminum and mild steel, and these are compared with results produced in rotating cantilever beam equipment. The resonance response, damping, and elasticity properties of a bolted joint were determined and the effects of bolt tension and molybdenum disulfide lubrication are illustrated and partially analysed.

TR 52-320 (Uncl)

December 1952

SUBJECT: EFFECT OF DAMPING CONSTANTS AND STRESS DISTRIBUTION ON THE RESONANCE RESPONSE OF MEMBERS.

INVESTIGATOR: B. J. Lazan

CONTRACT: AF 33(038)-18903

CONTRACTOR: University of Minnesota

ABSTRACT: The amplitude of vibration of a member at resonance, as defined by its resonance amplification factor, is analyzed in relationship to the damping properties of materials. Data are presented on damping energy to indicate the effect of stress magnitude, stress history and temperature. Based on the mathematical relationship found to exist between damping and stress magnitude the resonance amplification factors are determined for a variety of direct stress members and beams. It is shown that the amplification in vibration caused by resonance may be considered to be the product of three basic factors; (a) the mathematical factor, (b) the cross-sectional shape factor, and (c) the longitudinal stress-distribution factor. The first of these factors may be calculated from the damping and dynamic modulus properties of the material and the last two from the shape and loading characteristics of the member. Diagrams are presented to show these basic factors as functions of the damping exponent and other variables for members commonly encountered in engineering practice. Experimental data are presented to confirm the equations derived for resonance amplification factors of members having various shapes and stress distribution.

TR 5662, Part 4 (Uncl)

November 1952

SUBJECT: INVESTIGATION OF MECHANICAL PROPERTIES AND PHYSICAL METALLURGY OF AIRCRAFT ALLOYS AT VERY LOW TEMPERATURES. PART 4 - LOW TEMPERATURE MECHANICAL PROPERTIES, INCLUDING FATIGUE OF TITANIUM-BASE ALLOYS RC-130-B AND Ti-150-A.

INVESTIGATOR: Joseph W. Spretnak and Mars G. Fontana

CONTRACT: W33-038-ac-15698

CONTRACTOR: Ohio State University Research Foundation

**ABSTRACT:** The yield and ultimate strengths of both alloys increase as temperature is lowered. The increase in ultimate strength at  $-196^{\circ}\text{C}$  over the room temperature values is 72% in the case of RC-130-B and 61% in the case of Ti-150-A. Elongation and reduction of area of both materials are decreased at low temperatures. The effect of notching on tensile properties is to raise the yield and ultimate strengths at room temperature and  $-78^{\circ}\text{C}$  and to decrease these values at  $-196^{\circ}\text{C}$ . Apparently the notched tensile strength passes through a maximum between room temperature and  $-196^{\circ}\text{C}$ . Elastic moduli increase as temperature decreases.

Both alloys show low values of impact strength at room temperature, considering their tensile strengths, and the absorbed energy in the impact test drops to low values at temperatures below  $-78^{\circ}\text{C}$ .

Ti-150-A shows a remarkable high room temperature fatigue strength of 110,000 psi at  $10^7$  cycles. The fatigue strength at room temperature of RC-130-B is 84,000 psi. At  $-196^{\circ}\text{C}$  these values increase to 130,000 psi for RC-130-B and 141,000 psi for Ti-150-A. RC-130-B is less sensitive to notching in fatigue than Ti-150-A, except at  $-196^{\circ}\text{C}$ , at which temperature Ti-150-A is less notch sensitive than RC-130-B.

RC-130-B is slightly harder than Ti-150-A at all test temperatures. At  $-253^{\circ}\text{C}$  the hardness of both materials increases about 106% over the room temperature hardness.

The thermal expansion coefficient of RC-130-B is higher than that of Ti-150-A at all temperatures from room temperature down to  $-196^{\circ}\text{C}$ . The thermal expansion coefficients of both alloys decrease as temperature is lowered.

TR 6517, Part 1 (Uncl)

December 1951

**SUBJECT:** DETERMINATION OF PHYSICAL PROPERTIES OF NONFERROUS STRUCTURAL SHEET MATERIALS AT ELEVATED TEMPERATURES.

**INVESTIGATOR:** D. D. Doerr

**CONTRACT:** AF 33(038)-8681

**CONTRACTOR:** Armour Research Foundation Illinois Institute of Technology

**ABSTRACT:** In order to establish important design criteria, the compressive, bearing, and shear properties have been determined for (1) 24S-T3 aluminum alloy at room temperature and at elevated temperatures between 212 and  $700^{\circ}\text{F}$ , with exposure periods ranging from 0.5 to 1000 hr; (2) 75S-T6 aluminum alloy, FS-1H and MH magnesium alloys at room temperature and at elevated temperatures ranging from 300 to  $600^{\circ}\text{F}$ , for exposure periods of between 0.5 and 1000 hrs; (3) annealed and cold rolled titanium materials at room temperature and at several elevated temperatures between 400 and  $1000^{\circ}\text{F}$  for exposure periods of 0.5 and 100 hr. These proper-

ties have been compared with the tensile data in an attempt to establish a possible correlation of the compressive, bearing, and shear characteristics with the tensile properties of the individual material at elevated temperatures.

The test specimens, equipment, and procedure are described in detail. The test results are presented in the form of tables and curves to illustrate the effect of temperature and exposure time on physical properties of the various materials investigated. It is concluded that the results of this investigation will establish reliable data concerning the quantitative relationships between tensile and concomitant mechanical properties of selected structural sheet materials at elevated temperatures.

This is a summary report covering work conducted during the first year of the project. The project is being continued.

#### ELECTRODEPOSITION

TR 5692, Supplement 2 (Uncl)

November 1952

SUBJECT: AN INVESTIGATION OF ELECTRODEPOSITED ALLOYS FOR PROTECTION OF STEEL AIRCRAFT PARTS.  
INVESTIGATOR: A. B. Tripler, Jr., J. E. Bride, J. A. Gurklis, and C. L. Faust  
CONTRACT: AF 33(038)-8750  
CONTRACTOR: Battelle Memorial Institute  
ABSTRACT: Work done in this report covers the preparation and evaluation of eleven alloy deposits. Methods and solutions used for the preparation of both co-deposits and diffused coatings are listed. Results of "Wet-Dry" exposure tests, x-ray diffraction, potential - time data of various coatings have been tabulated. A graphical system for the better interpretation and rating of the "Wet-Dry" test was developed. Manganese-zinc alloy diffusion type coatings of 50% manganese and 50% zinc composition exhibited the most promising corrosion protection properties of the various coatings investigated. Seventy-two panels were prepared and are being tested in outdoor exposure in northern Florida in order to evaluate the corrosion protection afforded by manganese and manganese-zinc coatings as compared to zinc, zinc chromated, and cadmium coatings. It is believed that a co-deposited zinc-silver coating of 25% silver merits further investigation. Also further studies of corrosion products should yield information enabling the design of an alloy coating of maximum protection.

TR 5692, Supplement 3 (Uncl)

November 1952

SUBJECT: AN INVESTIGATION OF ELECTRODEPOSITED ALLOYS FOR PROTECTION OF STEEL AIRCRAFT PARTS.  
INVESTIGATOR: C. L. Faust, A. B. Tripler, Jr., C. R. Konecny, and W. C. Schickner

WADC TR 53-373

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CONTRACT: AF 33(038)-8750  
CONTRACTOR: Battelle Memorial Institute  
ABSTRACT: Previous work reported under this AFTR No. 5692 indicated that binary metallic systems, having manganese as one of the elements, might afford good cathodic protection to steel and be a superior coating to that of zinc or cadmium. Following a literature search, methods for electrodepositing various alloys of manganese were investigated. Manganese-zinc and manganese-tin coatings were prepared and tested under exposure conditions of alternate condensation and drying. Certain compositions of the two alloys protected steel longer than pure zinc coatings, however, they were inferior to pure cadmium coatings. The plating processes were not completely developed, and are not ready for practical application. Methods for plating manganese-nickel, manganese-chromium, manganese-iron, and manganese-molybdenum were also studied but with less success.

### FATIGUE

TR 52-148 (Uncl)

September 1952

SUBJECT: FATIGUE TESTING UNDER PROGRESSIVE LOADING-A NEW TECHNIQUE FOR TESTING MATERIALS.

INVESTIGATOR: E. Marcel Prot; E. J. Ward, Captain, Translator

ABSTRACT: A method of accelerated fatigue testing is described. Specimens are tested under cyclic stress increasing with time; the increase continuing until failure occurs. The failure stresses are plotted against the square root of the rate of the increase of load. It is proposed that a straight line drawn through the plotted points will intersect the ordinate of zero rate of increase at the endurance limit.

TR 52-234 (Uncl)

November 1952

SUBJECT: INVESTIGATION OF PROT ACCELERATED FATIGUE TEST.

INVESTIGATOR: E. J. Ward, Captain and D. C. Schwartz, Captain

ABSTRACT: Prot (reference 1) has proposed a method of accelerated fatigue testing. The method consists of continuously increasing the stress on a test specimen until failure occurs. Specimens are tested at several rates of increasing stress. Then the failure stresses are plotted against the square root of the rate of increasing stress. Prot then proposes that a straight line drawn through the failure stresses will intersect the zero rate of increasing stress at the endurance limit.

This project has investigated the validity of Prot's proposal for SAE 4340 steel and also for flash welded points in SAE 4340. The method was extended in an attempt to utilize statistical analysis of

the data to estimate scatter of stress at the endurance limit.

Prot's method gave an excellent estimate of the mean endurance limit and the scatter of the endurance limit of the SAE 4340 steel. However, for the flash welded points, although a fair estimate of the endurance limit was obtained, the estimate of the scatter was considered unsatisfactory.

Before Prot's method can be recommended for general use, even for steel, more extensive investigation must be conducted to confirm this preliminary study.

#### JOINING

TR 53-67 (Uncl)

May 1953

SUBJECT: DETERMINATION OF HYDROGEN AND OXYGEN IN INERT GASES.  
INVESTIGATOR: Robert E. Bowman, Major and Charles B. Hartley  
ABSTRACT: This report describes tests of a commercial apparatus which was used to determine the amount of oxygen and hydrogen impurities in inert gases. The determination consists of measuring the temperature rise which occurs when oxygen and hydrogen combine in the presence of oxygen (or hydrogen) in the inert gas. The operation of the apparatus was checked by measuring the oxygen and hydrogen impurities in a cylinder of welding grade argon. Oxygen and hydrogen impurities as low as 0.001% could be detected.

TR 52-143 (Uncl)

August 1952

SUBJECT: LITERATURE SURVEY ON WELD-METAL CRACKING.  
INVESTIGATOR: A. J. Williams, P. J. Rieppel, and C. B. Voldrich  
CONTRACT: AF 33(038)-12619  
CONTRACTOR: Battelle Memorial Institute  
ABSTRACT: As the initial part of an investigation for Wright Air Development Center on the causes of cracking in high-strength weld metal, a literature survey was made. Work on wrought and cast steel was included in this survey, since it is the most prolific source of information on this subject.

Of the various phenomena which might be pertinent, hot-tearing, hot shortness, blue brittleness, and hydrogen embrittlement appeared to be closely related to the cause of weld-metal cracking. Investigators agree that most weld-metal cracking initiates at high temperatures in the boundaries between grains or dendrites. This type of cracking is generally attributed to the presence on these boundaries of low-melting-point or "brittle" compounds -- complex sulfides, for example.

Most types of low-pressure cracks in weld metal appeared to be associated with rapid cooling rates and hydrogen. As a result of this survey, the experimental program on this investigation will involve weld-metal cracking tests, studies of grain-boundary constituents which might cause cracking, preparation of special weld-metal compositions, and tests to determine the temperature at which cracking occurs.

TR 52-294 (Uncl)

November 1952

SUBJECT: EFFECTS OF CARBON, OXYGEN, AND NITROGEN ON THE PROPERTIES OF WELDS IN TITANIUM SHEET.

INVESTIGATOR: D. C. Martin and C. B. Voldrich

CONTRACT: AF 33(038)-21385

CONTRACTOR: Battelle Memorial Institute

ABSTRACT: Three series of titanium alloys were melted and rolled into sheet. The first series included four titanium-carbon alloys with the carbon ranging from 0.13 per cent to 0.74 per cent. The second series contained three titanium-oxygen alloys with the oxygen ranging from 0.15 per cent to 0.55 per cent. The third series had two titanium-nitrogen alloys, one containing 0.13 per cent nitrogen, the other, 0.24 percent nitrogen. A 0.50 per cent nitrogen alloy was melted but could not be rolled into sheet. Inert-gas-shield arc welds were made in one-sixteenth inch and one-eighth inch sheets of each alloy. Spot welded specimens were made with 0.032 inch and 0.064 inch sheets of each alloy. The physical properties of both arc welds and spot welds in each alloy were determined. The data that was obtained will be useful in establishing the allowable percentages of carbon, oxygen and nitrogen impurities in titanium sheet.

TR 52-313, Part 1 (Uncl)

November 1952

SUBJECT: BRAZING TITANIUM TO TITANIUM AND TO MILD AND STAINLESS STEELS.

INVESTIGATOR: W. J. Lewis, P. S. Rieppel, and C. B. Voldrich

CONTRACT: AF 33(038)-23338

CONTRACTOR: Battelle Memorial Institute

ABSTRACT: Procedures and alloys suitable for brazing titanium were investigated. Commercial brazing alloys were evaluated by making brazed joints of titanium in a furnace containing an atmosphere of high purity argon. The most satisfactory alloys in this type of brazing were silver and silver base alloys. Joints with shear strengths averaging 15,000 psi were obtained by furnace brazing with the following alloys:

100% silver  
85% silver, 15% manganese  
45% silver, 15% copper, 16% zinc, 24% cadmium

Brazed joints of titanium were also made with the oxy-

acetylene torch and a commercial brazing flux. The best alloy found in torch brazing was a 45% silver, 15% copper, 16% zinc, 24% cadmium alloy, which produced shear strengths averaging 13,000 psi.

The strengths of brazed joints in titanium were somewhat lower than that of similar brazed joints of the same alloys in carbon steels. The lower strengths are believed to be associated with the inter-metallic compounds which formed at the boundaries between the brazing alloy and titanium. Also, broad zones of diffusion were present at some of the boundaries. Some of the inter-metallic compounds appeared to be brittle. Silver and the 85% silver-15% manganese alloy were the only brazing alloys that produced joints exhibiting some ductility.

In order to reduce compound formation and diffusion, a few preliminary tests were made using shorter brazing cycles. This was accomplished with induction, resistance, and shielded carbon-arc brazing methods. These tests indicated that the formation of inter-metallic compounds can be reduced by using shorter heating cycles. This phase of the investigation will be covered in more detail in a second report.

TR 52-322, Part 1 (Uncl)

November 1952

SUBJECT: CAUSES OF CRACKING IN HIGH-STRENGTH WELD METALS.

INVESTIGATOR: A. J. Williams, A. J. Jacobs, P. J. Rieppel and C. B. Voldrich

CONTRACT: AF 33(038)-12619

CONTRACTOR: Battelle Memorial Institute

ABSTRACT: In this investigation, the major part of the effort was devoted to making and testing a special apparatus for determining the hot ductility of weld metals. The apparatus was designed so that the test specimen could be tested in tension after the center section had been cooled directly from the molten state to a predetermined temperature. The center section was melted by induction heating and was retained in place by a mold of fused silica. Special equipment was designed and constructed to measure the load required to fracture the specimen and to measure the elongation. Techniques were developed to measure the temperature at the center section. The operation of the apparatus was checked by testing SAE 1018 and SAE 4340 steel specimens in the temperature range from 2588° to 1800°F after the center section was cooled directly from the melting temperature. The equipment was satisfactory and will be used in future tests to determine the effects of weld-metal composition on hot strength and hot ductility. Seven special heats of SAE 43XX steels were made with different sulfur and carbon contents. These steels will be included in future tests to determine the effects of carbon and sulfur on hot strength and hot ductility.

Some studies were made with weld-metal cracking test

specimens to develop a specimen that could be used in conjunction with the hot-ductility studies. Techniques were also developed for using the electron microscope in the study of grain boundaries of weld metals.

METALS, GENERAL

TR 52-89, Part 1 (Uncl)

August 1952

SUBJECT: PLASTIC BEHAVIOR OF ENGINEERING MATERIALS. PART 1 - AXIAL TENSION AND BENDING INTERACTION CURVES FOR MEMBERS LOADED INELASTICALLY.

INVESTIGATOR: D. O. Brush, O. M. Sidebottom, and J. O. Smith

CONTRACT: AF 33(038)-15677

CONTRACTOR: University of Illinois

ABSTRACT: This paper presents a theoretical method for constructing dimensionless interaction curves for members subjected to combined tension and bending loads that produce inelastic strains, and presents experimental results which verify the theory. Each interaction curve represents the total range of the ratios of axial load to bending moment which will cause inelastic strains to extend a given depth in the member. Experimental interaction curves were obtained from eccentrically loaded tension members of rectangular cross sections made from three strain hardening materials, namely, annealed rail steel and aluminum alloys 24S-T4 and 75S-T6. Good agreement was found between theory and experiment. In order to design a member subjected to combined axial and bending loads by use of the interaction curves, the lateral deflection of the member must be estimated. Three orders of approximation for the lateral deflection of eccentrically loaded tension members are presented. The problem of combined bending and axial compressive loads is discussed and research based on the methods of analysis developed in this investigation is suggested for solving the buckling load of a member subjected to combined bending and axial compressive loads. Some illustrative problems are solved in the appendix which show how the results of this investigation may be used.

TR 52-101, Part 1 (Uncl)

July 1952

SUBJECT: EQUIPMENT FOR TESTING THE CREEP PROPERTIES OF METALS UNDER INTERMITTENT STRESSING AND HEATING CONDITIONS.

INVESTIGATOR: Lawrence A. Shepard and John E. Dorn

CONTRACT: AF 33(038)-11502

CONTRACTOR: University of California

ABSTRACT: Very little is known about the separate or combined effects of intermittent heating and stressing on the elevated temperature creep and creep-rupture characteristics of aircraft structural metals. Such information is important since aircraft and engines will be subject to these conditions. Between flights, loads and tempera-



tures are low; during flights, they are high. Exact service conditions cannot be reproduced in the laboratory, but arbitrary cycles have been chosen for initial work. In view of the need for more complete information on the effects of such intermittent heating and stressing on the creep and creep-rupture properties of structural sheet materials, an experimental program on this subject was initiated. (Possible theoretical analyses of the results will be made later.) One of the major problems of the program was the development of suitable equipment for the investigation. A description of four creep testing machines, specially designed for this program, with automatic electronic control units is given herein. This equipment is designed to produce any combination, separately or simultaneously, of intermittent heating and stressing of creep-rupture specimens, in or out of phase.

TR 6517, Supplement 1 (Uncl)  
Part 1

February 1953

SUBJECT: DETERMINATION OF PHYSICAL PROPERTIES OF NONFERROUS  
STRUCTURAL SHEET MATERIALS AT ELEVATED TEMPERATURES.  
PART 1, SUPPLEMENT 1 - TYPICAL STRESS VS. STRAIN AND  
STRESS VS. DEFORMATION CURVES.

INVESTIGATOR: D. D. Doerr

CONTRACT: AF 33(038)-8681

CONTRACTOR: Armour Research Foundation Illinois Institute of  
Technology

ABSTRACT: This supplement has been prepared to present typical stress-strain curves in tension and compression, and stress-deformation curves in bearing for all materials tested on the basic contract. These curves were drawn from the original data obtained by laboratory tests. In presenting this information on the aluminum and magnesium alloys, families of curves were drawn for each test temperature in which time is a parameter. Therefore, each figure consists of five curves which represent the stress-strain or stress-deformation relationships existing at each elevated temperature for exposure times of 0.5, 2, 10, 100, and 1000 hours. For the titanium materials, each figure consists of five curves illustrating the stress-strain or stress-deformation relationships which exist at each of the two exposure periods at temperatures of 78, 400, 600, 800, and 1000°F.

These curves are presented for (1) 24S-T3 aluminum alloy at room temperature and at elevated temperatures between 212° and 700°F with exposure periods ranging from 0.5 to 1000 hours, (2) 75S-T6 aluminum alloy, FS-1H and Mh magnesium alloys at room temperature and at elevated temperatures ranging from 300 to 600°F for exposure periods between 0.5 and 1000 hours, and (3) annealed and cold-rolled titanium materials at room temperature and at several elevated temperatures between 400° and 1000°F

for exposure periods of 0.5 and 100 hours.

TR 6517, Part 2 (Uncl)

December 1952

SUBJECT: DETERMINATION OF PHYSICAL PROPERTIES OF FERROUS AND NON-FERROUS STRUCTURAL SHEET MATERIALS AT ELEVATED TEMPERATURES.

INVESTIGATOR: D. D. Doerr

CONTRACT: AF 33(038)-8681

CONTRACTOR: Armour Research Foundation of Illinois Institute of Technology

ABSTRACT: In order to establish important design criteria, the compressive, bearing and shear properties have been determined for (1) XA78S-T6 aluminum alloy sheet (clad), and FS-1a magnesium alloy at room temperature and at elevated temperatures ranging from 212° to 600°F, for exposure periods between 0.5 and 1,000 hours, (2) Heat Treat Nos. 1 and 2 of SAE 8630 alloy steel, SAE 4130 alloy steel, annealed stainless steel, and half-hard stainless steel, at room temperature and at several elevated temperatures between 400° and 1200°F for exposure periods ranging from 0.5 to 100 hours. These properties have been compared with the tensile data obtained under corresponding conditions in an attempt to establish whether a correlation exists which would permit prediction of the compressive, bearing and shear characteristics from the tensile properties of the individual material at room and elevated temperatures.

The test specimens, equipment, and procedures are described in detail. The test results are presented in the form of tables and curves to illustrate the effect of temperature and exposure time on the physical properties of the various materials under investigation.

TR 6678 (Uncl)

November 1951

SUBJECT: SURVEY OF CRITICAL AND STRATEGIC METALS.

INVESTIGATOR: Howard J. Siegel, 2/Lt.

ABSTRACT: Data are presented pertaining to three groups of critical metals (structural, ferroalloy, and plating metals) relevant to applications, production (world and domestic), and substitutes for these metals.

TR 6731, Part 1 (Uncl)

August 1952

SUBJECT: SHORT-TIME CREEP PROPERTIES OF STRUCTURAL SHEET MATERIALS FOR AIRCRAFT AND MISSILES.

INVESTIGATOR: J. A. VanECHO, L. C. Page, W. F. Simmons, and H. C. Cross

CONTRACT: AF 33(038)-8743

CONTRACTOR: Battelle Memorial Institute

ABSTRACT: This project was undertaken to determine the short-time creep strengths of several aircraft structural sheet materials at times up to approximately 100 minutes.

The materials tested included two magnesium alloys, three aluminum alloys, four steels, and two high-temperature alloys. Each group of materials was tested over the useful temperature range for the material in that group.

The testing procedure was to load the specimen cold, heat to the desired temperature by resistance heating, and hold at the test temperature until the test was completed. A slide-wire extensometer was used and the total extension of the specimen was recorded on a high-speed General Electric recorder.

The data are presented as time-deformation curves, design curves, and curves comparing the materials after one, ten, and sixty minutes of loading. Among the light alloys, 24S-T had the highest strength at all test temperatures. Steels containing titanium and boron had high strength but were very brittle. The high-temperature alloy L-605 in the hot-rolled condition had very good properties between 1200° and 2000°F.

TR 6731, Part 2 (Uncl)

May 1953

SUBJECT: SHORT-TIME CREEP PROPERTIES OF STRUCTURAL MATERIALS FOR AIRCRAFT AND MISSILES. METHOD OF TESTING FOR SHORT-TIME HIGH-TEMPERATURE CREEP PROPERTIES OF SHEET MATERIALS.

INVESTIGATOR: J. A. VanEcho, Ward F. Simmons, and H. C. Cross

CONTRACT: AF 33(038)-8743

CONTRACTOR: Battelle Memorial Institute

ABSTRACT: This report describes the methods employed in the testing of aircraft structural sheet materials for times ranging from a few seconds up to approximately 100 minutes. The methods and procedures described herein, which were used in obtaining test results and design curves published in AF Technical Report 6731, Part 1, are presented in detail. Such information is no longer generally available and modifications have been incorporated in their current usage.

This report covers all phases of the testing procedures, including the test specimen shape and size, testing frame and loading system, main heating power supply and control, temperature-measurement and control, and strain-measurement and recording system.

Methods of reporting test results are shown for a previously tested aluminum alloy. These results are given in forms of time-deformation curves, design curves and stress-total deformation curves.

#### PACKAGING

TR 53-22, Part 1 (Uncl)

April 1953

SUBJECT: PACKAGING STUDY OF AIR FORCE INSTRUMENTS.  
INVESTIGATOR: W. L. Hardy and Marvin Masel  
CONTRACT: AF 33(616)-211  
CONTRACTOR: Foster D. Snell, Inc.  
ABSTRACT: Packaged instrument accelerations resulting from a drop are calculated for linear cushions. An evaluation is made of the effects of non-linearity. Element damage due to instrument acceleration is described. This is done both for impact due to a drop and for forced vehicular vibration. A procedure is developed for finding an optimum cushioning material and thickness for an instrument of given unit loading and fragility rating. Methods of specifying the fragility of an instrument are discussed.

TR 53-43 (Uncl)

March 1953

SUBJECT: THE SELECTION OF CUSHION AREA IN THE DESIGN OF PACKAGE CUSHIONING.  
INVESTIGATOR: Roger B. Orensteen, 2/Lt.  
ABSTRACT: Criteria of package cushion area selection are discussed for minimizing cushioning volume and container cubage. Stress-strain, energy-stress, and ratio of stress to energy are shown for a typical cushioning material. Procedures are outlined for using the stress value corresponding to the minimum ratio stress to energy as a criterion in cushion area selection for optimum package design.

TR 53-68 (Uncl)

March 1953

SUBJECT: A TECHNIQUE FOR THE DESIGN OF GLASS FIBER PACKAGE CUSHIONING.  
INVESTIGATOR: Roger B. Orensteen, 2/Lt.  
ABSTRACT: A technique is demonstrated by which static cushioning data can be used in the design of glass fiber package cushioning. Design curves are provided for selecting density, thickness, and cushion area for economical cushion design. Consideration is given to the advantages of glass fiber cushioning of small area and high density.

#### PETROLEUM PRODUCTS, FUELS

TR 52-35 (Uncl)

June 1952

SUBJECT: RESEARCH ON THE FLAMMABILITY CHARACTERISTICS OF AIR-CRAFT FUELS.  
INVESTIGATOR: G. W. Jones, M. G. Zabetakis, and J. K. Richmond  
CONTRACT: AF 33(038)-50-1293-E  
CONTRACTOR: United States Department of the Interior

**ABSTRACT:** The results of limit of flammability, limit of ignitibility, and ignition temperature tests conducted on aircraft fuel vapor-air mixtures by the U. S. Bureau of Mines Gaseous Explosions Laboratory between February 19, 1950 and February 19, 1952 are presented. Two aviation gasolines grades 100/130 and 115/145, and two jet fuels grades JP-1 and JP-3, were investigated. A limited amount of work was done on the ignitibility of JP-1 mists and sprays, and on the ignition temperatures of aircraft hydraulic fluid AN-O-366.

In addition to the above results, sections are included on definitions and theory, and apparatus used for the investigation is described.

TR 6387 (Uncl)

March 1952

**SUBJECT:** STUDIES OF THE EFFECTS OF AVIATION FUEL COMPONENTS ON THE ACCURACY OF THE KARL FISCHER ELECTROMETRIC TITRATION METHOD FOR DETERMINING THE WATER CONTENT OF FUELS.

**INVESTIGATOR:** Robert W. Altman, Richard W. Sneed, and James C. Mosteller

**ABSTRACT:** A study was conducted to determine the effect of various concentrations of fuel components such as tetraethyl lead, aromatics, olefins, mercaptans and oxidation inhibitors on the accuracy of results obtained when determining water content of fuels by the Karl Fischer Electrometric Titration Method. Of the compounds investigated, only mercaptans appear to give any appreciable interference in water determination by this method.

TR 6390 (Uncl)

August 1952

**SUBJECT:** MODIFIED METHOD FOR DETERMINING OXIDATION STABILITY OF AVIATION FUELS.

**INVESTIGATOR:** Robert W. Altman, Richard W. Sneed, and James C. Mosteller

**ABSTRACT:** A modified test procedure developed in the Materials Laboratory, Directorate of Research, WADC, for the determination of the accelerated aging characteristics of aviation fuels is described. This test method appears particularly applicable to jet propulsion fuels forming large quantities of insoluble gum during oxidation. The major feature of the new procedure is the equipment modification which makes it possible to oxidize a sample and, without subsequent handling, determine the residue formed. This is considered an improvement over the present ASTM and Army-Navy gum methods. The results obtained with a wide variety of aviation fuels indicate the modified method to be generally as suitable as the current methods, but superior for fuels forming insoluble residues during accelerated aging.

TR 6625 (Uncl)

January 1952

**SUBJECT:** STABILITY OF JET (TURBINE) FUELS IN STORAGE.

INVESTIGATOR: C. A. Cole and A. C. Nixon

CONTRACT: AF 33(038)-7277

CONTRACTOR: Shell Development Company

ABSTRACT: The general objective of this investigation is to increase the permissible storage life of JP-3 jet fuels by employing methods which will result in the utilization of the simplest possible refinery treatments and which will result in maximum availability. This work is being done in two phases, in the laboratory using accelerated and hot room aging methods and under desert storage conditions at El Centro, California.

The early laboratory work was done under Navy Contract No. NOa(s)9970 and was designed primarily to survey possible experimental methods for investigating stability of jet fuels. On the basis of this work it was concluded that reasonable correlations could be established between accelerated and hot room aging and that the extent of deterioration could best be measured by use of the 500°F steam jet gum procedure. This procedure was found to give much more reproducible and consistent results than the 400°F air jet procedure for determining gum. Subsequently a variety of fuels have been tested to determine the effect of fuel properties, treatments, contaminants, composition and minor components on the storage stability. Numerous compounds have been tested for their effect as oxidation inhibitors. Some data have been accumulated on the effect of gum formation on the freezing point of the fuel. The problem of predicting stability from laboratory data has been given some consideration.

About 30 samples of jet fuels of various types were obtained from the major crude sources of the world (excluding Russia) and were put in storage at the El Centro Naval Air Station, El Centro, California. Containers used for these fuels consist of regular black iron 55 gallon drums and 5 gallon black iron cans. The effect of water contamination was studied in the 5 gallon cans by including similar series with distilled and sea water. Parallel experiments with vented and unvented cans have been run. Some fuels were tested also in 5 gallon galvanized iron and aluminum containers. The extent of deterioration in all these samples has been observed and correlated with the laboratory results.

The results of this study may be summarized as follows; the stability decreases with an increase in the end point of the fuel and an increase in the proportion of cracked components, high boiling cracked components being more deleterious than low boiling. Thermally cracked materials are more detrimental than catalytically cracked, particularly in the gas oil range. Soluble copper has an adverse effect on stability in thermally cracked and some straight run but not in catalytically cracked fuels. The presence of metallic copper is adverse in some SR fuels and in blends containing thermally cracked components. Generally speaking, water, either sea or distilled, has a beneficial effect.

Caustic treatment, particularly of catalytically cracked components, and acid treating show some favorable effect (particularly on inhibitor susceptibility) although the effect is not as marked as with gasoline. Some sulfur and nitrogen compounds catalyze the rate of gum formation. Color develops more rapidly than gum or aging.

Conventional gasoline inhibitors have, generally, little beneficial effect on the stability of these fuels. This includes the three inhibitors permitted in the MIL-F-5624 and 5161 specifications. A number of compounds have been found which show promise as inhibitors, particularly on the minimizing of insoluble gum. Dispersants have some beneficial effect in dispersing insoluble gum.

Only limited data are available for the effect of gum formation on freezing point but in two cases the freezing point has been increased significantly by the formation of rather moderate amounts of gum. However, the effect seems to be quite variable.

Gum forms in jet fuel as either soluble or insoluble gum and the latter may be either flocculant or adherent, depending on its physical nature. It is found that the soluble gum can reach quite high values (of the order of 1%) without resulting in the formation of any significant amount of insoluble gum. On the other hand, insoluble gum has been found in fuels containing less than 0.1% total gum. Accelerated conditions generally produce a greater proportion of insoluble gum than do normal aging conditions. Insoluble gum contains appreciably more oxygen than does soluble gum. It is not known if the soluble gum is a precursor of insoluble gum or not but it is possible that they are formed by different mechanisms. Both types of gum always contain more S and N<sub>2</sub> than does the substrate.

Elevated temperatures and oxygen pressures (such as are used in the specification test) are slightly less and more severe (respectively) than they are with cracked gasolines.

Correlations between accelerated, hot room and desert aging for the present fuels indicate that the 16 hour aging period in the MIL-F-5624 specifications is equivalent to more than 3 years of desert storage. The previous work (with U. S. samples only) indicated it was equivalent to about 2 1/3 years. In either case the specification appears unduly restrictive, in view of the present storage requirements of 3 years temperature zone bulk and 90 days desert drum storage.

This work is continuing with particular emphasis on the effect of inhibitors and on methods of minimizing the formation of insoluble residues. The effect of the introduction of JP-4 specifications

will be assessed. It has not been possible to analyze, as yet, all the data which have been obtained during the course of the present investigation. This will be done and the results presented in the next report.

TR 6625, Supplement 1 (Uncl)

October 1952

SUBJECT: STABILITY OF JET (TURBINE) FUELS IN STORAGE.  
INVESTIGATOR: C. A. Cole and A. C. Nixon  
CONTRACT: AF 33(038)-7277  
CONTRACTOR: Shell Development Company  
ABSTRACT: This is the final report under Supplemental Agreement Number One (May 1 to August 15, 1951) of Contract No. AF 33(038)-7277 on the storage stability of jet (turbine) fuels. This report briefly discusses proposed work to be carried out under the second supplemental agreement as well as recent progress made under the first extension.

Accelerated aging tests on four emergency fuels, produced in accordance with the requirements of the Military Petroleum Advisory Board Questionnaire, show them to be relatively stable with respect to total gum formed, although significant quantities of insolubles comprised part of the total. Data are also presented which confirm earlier results showing that iron and aluminum as container materials have no significant effect on fuel stability. A rapid filtration test designed for routine work to show relative filter clogging tendencies of fuels is discussed. Water and iron in combination appear to promote the formation of insoluble gum under hot-room conditions of aging although total gum is reduced. Further study of the correlations between desert and accelerated aging shows that accelerated aging tests are relatively more severe on cracked fuels than straight run fuels in comparison with the effect of desert storage.

#### PETROLEUM PRODUCTS, HYDRAULIC FLUIDS

TR 52-118 (R)

March 1953

SUBJECT: CHLORINE AND FLUORINE CONTAINING COMPOUNDS FOR NON-FLAMMABLE MATERIALS.  
INVESTIGATOR: Ogden R. Pierce and Earl T. McBee  
CONTRACT: W33-038-ac-19024  
CONTRACTOR: Purdue Research Foundation  
ABSTRACT: For use as possible base stocks for non-inflammable hydraulic fluids or additives thereof, the following classes of halogen containing compounds were prepared; Sulfides, Sulfones, Alcohols, Esters, Acids, Alkanes, Alkenes, Silanes, Phosphonites, and Phosphonates.



A review of the relationship between molecular structure and physical properties is presented. It was concluded that extension of this work into the field of fluorine-containing compounds is not practicable at this time, with the exception of spectrographic investigations.

A study of the rates of hydrolysis of the ethyl esters of mono-, di-, and trifluoroacetic acid has shown that the rate of hydrolysis increases with an increase in the fluorine substitution alpha to the carbonyl group.

An outline of future work is presented.

TR 6665 (R)

October 1951

SUBJECT: DIBASIC ACID ESTERS AND ESTER-TYPE FLUIDS AND LUBRICANTS.  
INVESTIGATOR: Merrell R. Fenske, Ph.D.  
CONTRACT: NOrd 7958-B (Joint Navy-Air Force)  
CONTRACTOR: Pennsylvania State College  
ABSTRACT: The work performed by the Petroleum Refining Laboratory, Pennsylvania State College, was directed toward the investigation of lubricants and fluids. These studies included oxidation stability, corrosion resistance, low temperature stability, lubricity of fluids and lubricants, thermal stability, shear stability, development of synthetic base stocks, lubricant additives, non-flammable fluids, viscosity index improvers, and fluid volatility.

TR 6685 (R)

November 1951

SUBJECT: DEVELOPMENT OF HIGH-TEMPERATURE AIRCRAFT HYDRAULIC FLUIDS.  
INVESTIGATOR: Neil W. Furby  
CONTRACT: AF 33(038)-9831  
CONTRACTOR: California Research Corporation  
ABSTRACT: The requirements for a nonflammable hydraulic fluid possessing favorable viscosity, volatility, and lubricity characteristics led to the investigation of the organo-silicates as possible new base materials to meet this demand. The studies conducted by the California Research Corporation have resulted in the synthesis of a number of siloxanes, disiloxanes, and organo-phosphorus compounds in an effort to develop a fluid that would meet the requirements as outlined in the three phases of their program. Data presented on mechanical test evaluation, viscosity-volatility relationships, viscosity-temperature characteristics, and fluid stability, indicate the potentiality of the organo-silicates as possible aircraft hydraulic fluids.

TR 6685, Supplement 1 (R)

October 1952

SUBJECT: DEVELOPMENT OF HIGH-TEMPERATURE AIRCRAFT HYDRAULIC FLUIDS.

INVESTIGATOR: Neil W. Furby  
CONTRACT: AF 33(038)-9831  
CONTRACTOR: California Research Corporation  
ABSTRACT: A high temperature silicate base hydraulic fluid capable of operating from -65°F to over 400°F was formulated from a mixed monomer orthosilicate base stock, a silicone viscosity index improver and a basic amine inhibitor to retard oxidation and hydrolysis. Various additives were evaluated for their effect on oxidation, viscosity, hydrolysis, lubricity, and flammability properties of silicate formulations. Further synthesis work was done on silicate and phosphonate esters as new base materials. Bench-scale wear tests and gear and piston type hydraulic pump tests were carried out on experimental hydraulic fluids

PETROLEUM PRODUCTS, LUBRICANTS

TR 53-25 (R)

May 1953

SUBJECT: DEVELOPMENT WORK ON LUBRICANTS FOR AIRCRAFT TURBINE ENGINES.  
INVESTIGATOR: E. Erwin Klaus and Merrell R. Fenske  
CONTRACT: AF 33(038)-18193  
CONTRACTOR: Pennsylvania State College  
ABSTRACT: Work on the synthetic ester type of gear lubricant has been continued. An experimental gear lubricant PRL 3161 has been proposed as an improvement over PRL 3059 gear lubricant. PRL 3161 has been prepared to give improved oxidation and corrosion stability under the severe conditions of the turbine bearing. Advantages of PRL 3161 over di-2-ethylhexyl sebacate and Specification AN-O-3M mineral oil in viscosity-temperature characteristics are illustrated.

Comparison of the four-ball wear data with the turbo-prop gear box results indicates some agreement between (a) good anti-wear properties and a high point of incipient seizure in the wear tests, and (b) satisfactory operation in the turbo-prop engine and gear box. The four-ball wear tests do not evaluate the viscosity function of a lubricant.

Fourteen different organic phosphates have been evaluated as anti-wear and E.P. additives in the four ball machines. The wear characteristics imparted by the phosphate or acid phosphates additives are substantially the same for alkyl, aryl, alkyl-aryl organic constituents.

Oxidation and corrosion characteristics of experimental synthetic ester gear lubes have been measured by means of six different procedures using aluminum, magnesium, steel, copper, cadmium-plated steel, silver-plated steel, and lead-indium coated silver-plated steel as metal catalysts in some of the tests.

A survey of the thermal stability of various esters has been made to 500°F. under a nitrogen atmosphere.

Wear characteristics of several ester type gear lubes have been determined after subjecting the fluid to various oxidation and corrosion tests. These values are then compared with similar values for the unused fluids. These results are indicative of the persistence of the anti-wear and E. P. additives under conditions of severe accelerated use.

PRL 3161 fluid has been service tested for a total of 237 hours in a T-38 Allison turbo-prop engine. The lubrication problems encountered in this test are outlined briefly. Properties of the used PRL 3161 fluid taken from this test are discussed. The properties evaluated include viscosity, neutralization number, wear and lubrication, and oxidation and corrosion stability. PRL 3161 exhibits excellent stability in service use.

Many of the studies in this report are basic on fluids using di-2-ethylhexyl sebacate as the base stock. An additional investigation has been made on other esters that are important commercially for the preparation of PRL 3161 type fluids.

A specification has been suggested for use in the commercial procurement of synthetic gear lubricants of the type discussed in this report.

TR 53-45 (R)

June 1953

SUBJECT: SYNTHETIC LUBRICANTS.  
INVESTIGATOR: D. W. McCready  
CONTRACT: W33-038-ac-211457  
CONTRACTOR: Engineering Research Institute University of Michigan  
ABSTRACT: This project was established to study the possibility of synthesizing a pure compound to be used as a synthetic lubricant in aircraft engines operating at ambient temperatures ranging from -65 to 160°F. The syntheses of the 84 compounds prepared are described in this report. The viscosity-temperature characteristics and melting points of the compounds have been determined. Other physical properties such as density, vapor pressure, specific heat, thermal conductivity, etc., have been determined on some of the compounds.

None of the compounds synthesized meets the viscosity specification of 65 cSt. at 210°F and 3000 cSt. at -65°F. The compounds which most nearly meet this specification and which show the greatest promise of meeting the specification are compounds having the "dumbbell" structure with terminal cyclopentyl rings along with the thioether structure.

May 1953

SUBJECT: CHLORINE AND FLUORINE CONTAINING COMPOUNDS FOR NON-FLAMMABLE MATERIALS.  
INVESTIGATOR: Ogden R. Pierce and Earl T. McBee  
CONTRACT: W33-038-ac-19024  
CONTRACTOR: Purdue University  
ABSTRACT: A number of bromine-containing compounds were evaluated as snuffer additives in MIL-O-5606 fluid. The most effective materials for this purpose were found to be brominated aliphatic hydrocarbons of short chain length.

For the studies of new base stock oils several new classes of fluorine and/or silicon containing materials were investigated. A series of compounds containing both silicon and phosphorus were synthesized and were found to possess good viscosity and non-flammability properties. Various fluorine-containing crotonyl and phosphonate ester systems were studied and the preparation and reactions of n-heptafluoropropyllithium investigated. The synthesis and evaluation of a fluorine-containing polyether and fluorine-containing silicate ester were also carried out.

TR 53-83 (Uncl)

July 1953

SUBJECT: DEVELOPMENT AND EVALUATION OF HIGH TEMPERATURE GREASES.  
INVESTIGATOR: Cecil G. Brannen and Edward A. Swakon  
CONTRACT: AF 33(038)-23687  
CONTRACTOR: Standard Oil Company  
ABSTRACT: In the work directed toward the development of an aircraft grease suitable for use over a wide temperature range, emphasis has been placed on the development of thickeners for silicone oil and on the evaluation of silicone-oil greases at high temperatures. Studies were made on one hundred and one silicone-oil greases containing as thickeners representatives of ten classes of materials that might be expected to produce thermally stable greases. Each composition was subjected to simple laboratory tests for preliminary evaluation, and twenty-nine compositions were run in the ABEC-NLGI bearing tester. The greases containing inorganic thickeners showed poor performance in the bearing tester, all failing in less than one hundred hours at 450°F. Several tests of two hundred hours or more were obtained with copper phthalocyanine, calcium acetate, and urea greases. One test of six hundred and fifty hours was obtained with a grease containing p-carboxydiphenylurea as thickener. This test satisfies the high-temperature bearing-test requirement of the contract.

TR 6385 (Uncl)

March 1953

SUBJECT: THE EFFECT OF STORAGE ON THE PHYSICAL CHARACTERISTICS OF GREASE.

INVESTIGATOR: Robert J. Burger and Bernard Rubin  
ABSTRACT: The effect of prolonged storage under accelerated conditions on three types of specification greases is described. Periodic tests using standard methods including penetration, oxidation stability, and low temperature torque were performed on samples of the greases packed both in cans and in bearings. Data thus obtained over the 24 months storage period at 130°F are tabulated and trends are presented graphically. The Specification AN-G-15 types of greases were found to harden appreciably in storage while two of the Specification AN-G-3 greases studied showed marked increases in consistency after being stored only a few months. Other Specification AN-G-3 greases, as well as one Specification AN-G-25 grease tested, appeared to be affected only slightly by extended storage under the conditions described.

TR 6386 (Uncl)

March 1953

SUBJECT: A STUDY OF THE RUST PREVENTIVE PROPERTIES OF GREASES.  
INVESTIGATOR: Bernard Rubin and Robert J. Burger  
ABSTRACT: As a result of numerous complaints of corrosion of wheel bearings of aircraft in semi-storage conditions, an investigation into the rust preventive properties of wheel bearing greases was initiated. Concurrent studies were carried out in the laboratory and in service aircraft.

A laboratory procedure using ball bearings as specimens exposed to 95% relative humidity at 100°F. was found to grade greases with respect to corrosion preventive properties under high humidity conditions. Furthermore, the test showed correlation with service results.

The laboratory investigation was enlarged to include many different types of greases. These included petroleum, various types of diesters, and silicone greases. Factors influencing the degree of corrosion resistance were investigated, including the effect of rust and oxidation inhibitors.

The service investigation was conducted on a group of operational aircraft over a period of one year. During this time, samples of the wheel bearing greases were removed periodically and records were maintained showing flying time and weather data.

The results of the investigation indicate that certain properties such as high alkalinity and some water-emulsifiability with a degree of water resistance are useful in controlling the degree of corrosion protection which a grease affords, to a coated bearing surface. Some difference in corrosion protective qualities was noted among the different classes of diester greases studied. Fingerprint suppression appears to have a role in protection against corrosion of steel surfaces

under service conditions.

PLASTICS, STRUCTURAL

TR 52-5 (Uncl)

January 1952

SUBJECT: HIGH STRENGTH EPON LAMINATES.  
INVESTIGATOR: F. C. Hopper and D. W. Elam  
CONTRACT: AF 33(038)-19587  
CONTRACTOR: Shell Development Company  
ABSTRACT: Epoxide (EPON) resin glass fabric base laminates have been developed with high mechanical strength properties at room temperature. Initial work was conducted to determine which type of laminating resin, (some of which were liquid and some solid), what type of application procedure, and what type and amount of curing agent, would give the optimum mechanical strength properties. It was found that applying the solid EPON resins 1001, 1004, and 1007, from solution gave more reproducible and higher mechanical strength properties than the liquid EPON resins RN-34 and RN-48.

Laminates fabricated using EPON 1001 with four parts of dicyandiamide per hundred parts of resin and 181-114 glass fabric gave consistent flexural strength values of at least 75,000 psi dry and 62,000 psi wet at room temperature. These epoxide resin, EPON 1001, laminates were cured at a pressure of 25 psi and at a temperature of 165°C (329°F) using four parts of dicyandiamide per hundred parts resin as the curing agent. The fabric was impregnated with a solution of equal weights of solid resin and acetone and dried for 20 minutes at 95°C. It was found that the greatest flexural strengths were obtained with cured laminates of 28 to 32 per cent resin content. Ultimate dry compressive strengths at room temperature, ranging from 57,000 to 74,500 psi, have also been obtained using EPON 1001 resin. Special finishes for the glass cloth resulted in EPON 1001 laminates having flexural strengths above 80,000 psi.

In general, it has been found that EPON resins are capable of producing laminates with higher strength at room temperature than other types of low pressure laminating resins, but the elevated temperature properties appear to be poorer than those of other low pressure laminates. The important point, as far as aircraft structural applications are concerned, is that it appears that edgewise compressive strengths up to twice that of other low pressure laminates may be obtainable.

TR 52-5, Supplement 1 (Uncl)

December 1952

SUBJECT: HIGH STRENGTH EPON LAMINATES.  
INVESTIGATOR: F. C. Hopper and D. W. Elam

CONTRACT: AF 33(038)-19587  
CONTRACTOR: Shell Development Company  
ABSTRACT: A laminate made from 181-114 glass fabric and EPON 1001 resin cured with dicyandiamide had a flexural strength of 76,900 psi at room temperature and 76,200 psi at 160°F (after 1/2 hour at 160°F). The compressive strength was 70,200 psi at room temperature.

With EPON laminates of this type, either boiling in water or aging at 95-100% relative humidity and 100°F for one hour caused a greater loss in strength than soaking for 30 days.

Improved Volan finish was the best of four new fabric finishes used in laminating with EPON 1001 and was the only finish better than 114.

Remarkably high strengths at elevated temperatures were obtained with an experimental resin known as EPON X-12100. Laminates made with this resin had a flexural strength above 60,000 psi at 392°F after 30 minutes at that temperature.

Liquid EPON resins 828 and 834 cured with dicyandiamide also produced laminates resistant to temperatures up to 300°F. After 1/2 hour at that temperature flexural strengths up to 44,000 psi were obtained. Aging for 200 hours at 300°F resulted in 52,900 psi flexural strength in one laminate. At higher temperatures, strengths fell off markedly.

Dimethyl cyanamide, a liquid curing agent, used with EPONS 828 and 834 produced laminates having up to 53,100 psi flexural strengths at 392°F. This curing agent is toxic.

Flexural strengths at 300°F after 1/2 hour at 300°F up to 54,400 psi were obtained also in laminates made with mixtures of Plyophen 5015 (a phenolic resin) and EPON 1001, cured with dicyandiamide.

Of four large laminates 1/8" x 38" x 96" made with EPON 1001 at 25 psi, one was of excellent quality and another was considered good. There should be no difficulty in making EPON laminates of any large area.

TR 52-75 (Uncl)

November 1952

SUBJECT: EFFECTS OF LAMINATING PRESSURE ON THE MECHANICAL STRENGTH OF GLASS FABRIC POLYESTER LAMINATES.  
INVESTIGATOR: J. E. Wier and D. C. Pons  
CONTRACT: P. O. (33-038)-50-1463-E

CONTRACTOR: National Bureau of Standards

ABSTRACT: The effects of laminating pressure and mold type on the mechanical strength and related properties of woven glass-fiber reinforced plastics were determined on laminates bonded with three commercial resins and laminated at four pressures and in two types of molds.

The resins used in making the laminates were diallyl phthalate DAP 65/55, made by the Shell Chemical Company, Plaskon 911-11, a polyester made by the Libbey-Owens-Ford Glass Company, and Selectron 5003, a polyester made by the Pittsburgh Plate Glass Company. The glass fabric used was Fiberglas 181-114 made by the Owens-Corning Fiberglass Corporation. Laminating pressures of 1, 10, 30, and 50 lb/in.<sup>2</sup> were used. Laminating was done in a closed mold, where the resin was confined, and between open platens (free-edge) where the excess resin was free to flow out under pressure.

The finished laminates were tested for flexural strength and modulus, tensile strength and modulus, and compressive strength. The strengths were determined on specimens both in a dry condition and in a wet condition after 30 days' immersion in water. Other tests included specific gravity, resin content, void content, and water absorption.

The flexural, tensile, and compressive strengths of laminates bonded with the three resins generally increase with an increase in laminating pressure. Laminates attained highest strengths at laminating pressures of 30-50 lb/inch<sup>2</sup>.

It was observed that although the tensile strength of the laminates increased with an increase in molding pressure, the tensile breaking load remained relatively constant. No consistent trend was found in the effect of laminating pressure on the percent loss of strength due to water immersion.

An increase in molding pressure also generally increased the specific gravity and decreased the voids content of the laminates.

Some effects of resin aging were observed in laminates bonded with Plaskon 911-11 and Selectron 5003 resins.

TR 52-142 (Uncl)

May 1953

SUBJECT: POST-MOLDING SHRINKAGE CHARACTERISTICS OF SOME THERMO-SETTING PLASTIC MOLDING MATERIALS.

INVESTIGATOR: Steven T. Marshall, 2/Lt., and Charles P. Ellis, Jr.

ABSTRACT: The dimensional stability as to post-molding shrinkage of commercially available melamine, phenolic and polyester plastic



molding materials was investigated by means of accelerated conditioning procedures which produced shrinkage corresponding to that obtained on parts in service in long-time aging. It is concluded, that of the materials tested, the polyester mineral filled molding material demonstrated the greatest degree of dimensional stability.

TR 52-161 (R)

July 1952

SUBJECT: DEVELOPMENT OF HIGH-STRENGTH, HEAT-RESISTANT PHENOLIC LAMINATING RESIN.  
INVESTIGATOR: M. N. Korelitz  
CONTRACT: W33-038-ac-21090  
CONTRACTOR: Cincinnati Testing and Research Laboratories  
ABSTRACT: The development of a high temperature resistant glass base phenolic laminate is described. Flexural ultimate strength values of the laminate with 181-1114 glass fabric at 500°F after one-half hour at 500°F pressed at 15-35 psi pressure average 40,000 psi. This is for 1/8 in. thick laminates up to 36 in. x 36 in., the larger size panels being bag molded. On these panels bag molded by North American Aviation, values of 35,000-45,000 psi were obtained at elevated temperatures. The higher values for bag molded panels have been obtained on 36 in. x 36 in. direct compression panels but they have not been obtained consistently to date. On direct compression panels 36 in. x 36 in. values from 25,000-30,000 psi have been obtained consistently at 500°F after 1/2 hr at 500°F. Values up to 55,000 psi can be obtained consistently for small laminates (such as those used in experimental compressor blades for jet engines) made at pressures in the range of 200-300 psi.

Initially these large panels 18 in. x 18 in. x 1/8 in., and 36 in. x 36 in. x 1/8 in., when handled in the same manner as 6 in. x 6 in. x 1/8 in. panels, resulted in sheets with deteriorated surfaces and lowered flexural strength at elevated temperatures, (20-25,000 psi). Since the material is applicable where larger sections with good high temperature resistance is necessary, work was continued in attempting to make satisfactory large panels.

It was found that different methods of impregnation of the resin on the glass and different methods of handling were necessary. Work along these lines has reached the point where the objective of 40,000 psi flexural strength at 500°F after 1/2 hr at 500°F has been obtained on specimens from panels 36 in. x 36 in. x 1/8 in. (Bag molded).

Fabrication techniques for parts of various sizes and configurations are described.

Some data on long-time temperature tests are reported. Some preliminary evaluations of laminates with various finishes on the glass cloth are presented.

The material used in making all panels except those for checking the finishes were made on production size equipment.

TR 52-183 (Uncl)

December 1952

SUBJECT: ANNUAL REPORT ON RESEARCH FOR USE IN ANC-17 BULLETIN,  
"PLASTICS FOR AIRCRAFT."  
INVESTIGATOR: Donald G. Coleman  
CONTRACT: AF 18(600)-70  
CONTRACTOR: United States Department of Agriculture  
ABSTRACT: Developments in the program of research in plastics for aircraft conducted by the U. S. Forest Products Laboratory are summarized. The approach has been in general to derive design criteria mathematically and then to check by test. Thirteen technical reports issued during the several years this project has been under way are abstracted.

TR 6220, Supplement 1 (Uncl)

December 1951

SUBJECT: DEVELOPMENT OF SIZINGS FOR GLASS FABRIC IN POLYESTER-  
RESIN LAMINATES.  
INVESTIGATOR: Johan Bjorksten, James E. Henning, Luther L. Yaeger,  
and Robert J. Roth  
CONTRACT: AF 33(038)-8902  
CONTRACTOR: Bjorksten Research Laboratories  
ABSTRACT: AF Technical Report No. 6220 describes the development of a glass fabric sizing consisting of vinyl trichlorosilane in conjunction with beta chloroallyl alcohol. Glass-fabric polyester-resin laminates utilizing this sizing on the fabric retained 90% or more of their dry flexural strengths after immersion in boiling water as compared to a 60% retention for laminates with commercial chrome complex (Finish 14) sized glass fabric.

Additional compounds were investigated as sizings for Number 181 glass fabric. None of these proved as effective as vinyl trichlorosilane in conjunction with betachloroallyl alcohol.

Pilot plant equipment for continuous processing of glass fabric by both liquid phase and vapor phase application of the silane sizings was constructed and operated and the effects of varying the processing conditions were studied. The properties of laminates from glass fabric treated by either process have been comparable.

The liquid phase processing involves passing the fabric through a 3.5% xylol solution of an equimolar mixture of vinyl trichlorosilane and betachloroallyl alcohol, drying to remove xylol, washing to hydrolyze chlorine remaining on the fabric, and drying. In vapor phase

processing, the fabric is sized in a chamber containing vinyl trichlorosilane vapor, washed, and dried.

TR 6220, Supplement 2 (Uncl)

June 1953

SUBJECT: DEVELOPMENT OF GLASS SIZINGS TO OBTAIN IMPROVED PROPERTIES OF GLASS FIBER LAMINATES MADE WITH MELAMINE, PHENOLIC, SILICONE, AND EPOXIDE RESINS.

INVESTIGATOR: Johan Bjorksten, Karl Guenther, Howard L. Gottlieb, and Robert J. Roth

CONTRACT: AF 33(038)-8902

CONTRACTOR: Bjorksten Research Laboratories

ABSTRACT: Various functional organo-silicon derivatives were investigated as glass fabric sizing for improving glass fiber laminates made with melamine, phenolic, silicone and epoxide resins. These sizings were compared with commercially available glass finishes and the vinyl trichlorosilane sizing previously developed for polyester-resin glass fiber laminates. The criteria used for evaluation were the dry and wet flexural strengths of the laminates prepared with these components.

For laminates made with the specified resins, the following results were obtained:

1. Epoxide Resin - chlorophenyl trichlorosilane and aminophenyl trichlorosilane improved laminate properties significantly.
2. Silicone Resin - chlorophenyl trichlorosilane improved laminate properties slightly.
3. Melamine Resin - aminophenyl trichlorosilane improved laminate properties significantly.
4. Phenolic Resin - none of the organo-silicon derivatives were effective in improving the properties of laminates with a 114 finish.
5. Application of vinyl trichlorosilane sizing was ineffective in improving laminates made with these resins.

TR 6223, Supplement 1 (Uncl)

May 1953

SUBJECT: DEVELOPMENT OF LOW-PRESSURE LAMINATES OF GLASS FABRIC AND SILICONE RESINS.

INVESTIGATOR: Kenneth R. Hoffman

CONTRACT: AF 33(038)-9201 S-1

CONTRACTOR: Dow Corning Corporation  
ABSTRACT: Methods for the production of low pressure laminates of Dow Corning Silicone Resin 2104 on a commercial scale have been worked out. Data are given on the preparation of laminating stocks, catalysis, preforming, laminating, bag molding, and molding in matched metal dies. The preparation of duct work and tubing are also discussed.

An evaluation of the use of the new glass fabric sizings with silicone resins shows that most can be used with Dow Corning Silicone Resin 2104, but heat cleaning gives the best results because of the consistent properties of the glass.

An evaluation of new resins, new sizes, catalysts, and additives for Dow Corning Silicone Resin 2104 are given.

TR 6602 (Uncl)

June 1952

SUBJECT: HEAT RESISTANT LAMINATING RESINS.  
INVESTIGATOR: Robert G. Nelb, Charles H. Alexander, and Paul M. Elliott  
CONTRACT: AF 33(038)-11821  
CONTRACTOR: United States Rubber Company  
ABSTRACT: A heat resistant, low pressure molded, polyester resin has been developed which will produce a glass fabric base laminate with good strength properties at elevated temperatures. Flexural ultimate strengths of the laminate using 181-144 fabric and the new resin designated as Vibrin X-1047 were from 43,000 to 47,000 psi, and from 23,000 to 31,000 psi after 1/2 hour exposures to 300°F and 500°F respectively when tested at these temperatures. A second resin producing laminate having somewhat lower high temperature flexural strengths, but which was self-extinguishing, was developed and designated Vibrin X-1422. Each of these resins utilized the tri-functional monomer, triallyl cyanurate, as the cross linking agent, together with conventionally constructed alkyds.

It was determined that, in order to obtain these properties for short-time exposures, postcures of 3 hours at 500°F, 8 hours at 450°F or larger periods at lower temperatures were required.

The fabrication techniques for these resins are similar to those of other polyester resins except, in order to prevent blistering of the laminate on postcure, it was found that moisture on the fabric, due to the humidity of storage, must be removed before impregnating or that the laminate must be dried by heating in an oven for 24 hours at 220°F prior to postcuring.

The electrical properties, dielectric constant and loss tangent, at 10,000 megacycles of the Vibrin X-1047 casting and glass fabric

base laminates are very good. The room temperature properties, dry, for the casting and laminate meet the requirements for radar use of the Air Force specification covering polyester resins. The loss tangent and dielectric constant increase only slightly with temperatures up to 500°F.

An improved method of preparing triallyl cyanurate in large laboratory batches in yields of 95% has been developed. This method uses sodium hydroxide in place of metallic sodium which has been previously used. The purity and color of the triallyl cyanurate have also been improved provided the starting material, cyanuric chloride, is of good grade.

TR 53-192, Part 1 (R)

July 1953

SUBJECT: MECHANISM OF RAIN EROSION. PART 1 - IMPACT PRESSURE IN SOLID-LIQUID SPHERE COLLISIONS.

INVESTIGATOR: Olive G. Engel

CONTRACT: D. O. 33(616)-53-9

CONTRACTOR: National Bureau of Standards

ABSTRACT: An equation for the pressure which results on impact of a fast moving surface with a water sphere is developed. The pressure equation and other results, which can be deduced from the assumptions made, are able to offer an explanation of certain experimental rain erosion data. Specifically, (1) the larger raindrops of a three-inch-per-hour rainfall should be more destructive than the smaller drops of a one-inch-per-hour rain, (2) the diameter of eroded holes at a velocity of 400 miles per hour should lie in about the range which is observed, and (3) on the assumption of a spall type tensile failure glass should be expected to be rain erosion resistant whereas hard plastics and aluminum should fail. The results are also in agreement with the experimentally observed fact that the horizontal wash (which exists first as spray) has a greater velocity than the impacting surface.

TR 52-20 (R)

September 1952

SUBJECT: A STUDY OF THE RAIN EROSION OF PLASTICS AND METALS.

INVESTIGATOR: John L. Beal, Roy R. Lapp, and Norman E. Wahl

CONTRACT: AF 33(038)-514

CONTRACTOR: Cornell Aeronautical Laboratory, Inc.

ABSTRACT: Studies of the erosion behavior, as well as the factors influencing the rate of erosion, at 500 mph, of soft, resilient, polymeric materials and hard, relatively inelastic materials such as metals, were carried out. Neoprene base coatings designated as Gates N-79 (N-700-9 with N-300-9 catalyst) and Goodyear 23-56 (both with Bostik 1007 primer) are considered to have the most satisfactory rain erosion resistance applied to structural plastics and metals at speeds up to six hundred and fifty miles per hour.

The rain erosion resistance of metals commonly used in exterior aircraft construction was tested. Of those metals, titanium had the best erosion resistance, which may be attributed to its toughness.

Studies of the general nature of the phenomenon of rain erosion indicate that it is one of impact fatigue.

TR 52-105 (Uncl)

December 1952

SUBJECT: RAIN EROSION OF MATERIALS.  
INVESTIGATOR: Gordon C. Williams  
CONTRACT: AF 33(038)-12606  
CONTRACTOR: University of Louisville  
ABSTRACT: High speed flight through rain causes erosion damage to exterior plastic and metal parts of aircraft, particularly leading edges. This report summarizes the work conducted at the University of Louisville to study rain erosion and suitable materials or coatings to resist rain erosion.

The original objective of this project was to determine the rain erosion properties of some plastic and metal materials at supersonic speeds, but tests were able to be conducted only from average speeds of 250 to 700 mph, employing a water spray to simulate rain.

Neoprene coatings were found to provide good rain erosion resistance for plastic laminates.

#### RUBBER

TR 52-338 (Classified)

December 1952

SUBJECT: USAF REQUIREMENTS FOR RUBBER MATERIALS. (Uncl)  
INVESTIGATOR: Captain W. Postelnek  
ABSTRACT: Both operational and environmental conditions profoundly affect the desirable properties of rubber materials used in military aircraft. Many requirements exist for improved elastomeric materials which will retain their rubbery properties over a wide temperature range in contact with various fuels, oils and corrosive chemicals, as well as on exposure to adverse atmospheric phenomena. Currently, a research and development program is geared to provide solutions to the more pressing problems. (Uncl)

TR 52-180 (Uncl)

August 1952

SUBJECT: INVESTIGATION OF SILICATE ESTERS AS RUBBER PLASTICIZERS.  
INVESTIGATOR: Donald L. Byerley, 2/Lt.

ABSTRACT: A number of silicate esters, submitted by the John B. Pierce Foundation, Raritan, New Jersey, were evaluated as low-temperature rubber plasticizers. An attempt was also made to correlate structural variations of the esters with the properties imparted to the compounded rubber. It was found that, in general, as the ratio of the number of aliphatic carbon atoms/number of phenyl groups increased the ASTM brittle point was lowered. Variation of the structure of the silicate ester, on the other hand, appeared to have little effect on the physical properties (e.g. tensile strength, modulus, and elongation). Compatibility with common base polymers (Paracril 18, Paracril 35, and Neoprene W) decreased rather rapidly as the above ratio increased beyond a value of about 2.5. Extrapolation of these results indicates that a ratio value above 20 would not permit incorporation of a sufficient amount of the silicate ester to affect the low temperature properties of the compound stock significantly.

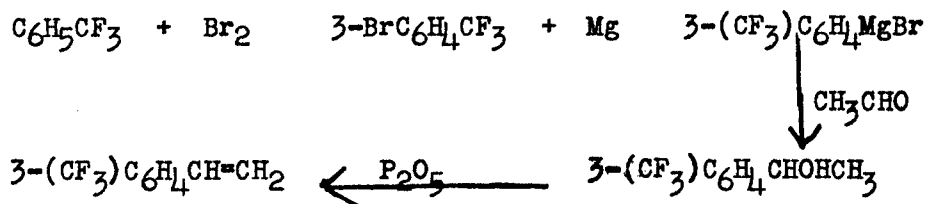
TR 52-191, Part 1 (Uncl)

October 1952

SUBJECT: FLUORINE CONTAINING ELASTOMERS.  
 INVESTIGATOR: O. R. Pierce and E. T. McBee  
 CONTRACT: AF 33(038)-20581  
 CONTRACTOR: Purdue Research Foundation  
 ABSTRACT: The nature of the work described in this report embraced the synthesis of two types of materials; (a) fluorine-containing silicones, and (b) fluorine-containing styrenes copolymerized with butadiene. These materials are to be evaluated as low-temperature, fuel-resistant elastomers.

The fluorine-containing silicones were synthesized by routes employing the reaction of a fluorine-containing Grignard reagent with silicon tetrachloride or tetraethyl silicate followed by hydrolysis of the monomer silane obtained. In particular, the monomer,  $(C_3F_7CH_2CH_2)_2SiX_2$  ( $X=Cl$  or  $OEt$ ) was prepared. Also, a perfluoroalkyl Grignard reagent,  $C_3F_7MgI$ , was synthesized and its utility in the preparation of perfluoroalkyl silicones studied. At the conclusion of the first year's work, the achievements indicate that the synthesis of highly fluorinated silicone elastomers is feasible and the research is being continued.

The fluorine-containing styrenes were prepared by known methods as follows:



Three monomers were obtained in this way: 3-(trifluoromethyl)styrene,

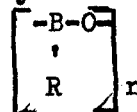
3,5-bis(trifluoromethyl)styrene, and 2,5-bis(trifluoromethyl)styrene. These materials were copolymerized with butadiene using an emulsion technique. After preparation of polymer samples was complete, the work was discontinued in this laboratory and no further investigations along this line are contemplated.

TR 52-192 (Uncl)

June 1952

SUBJECT: INVESTIGATION OF THE SYNTHESIS AND TESTING OF VARIOUS POSSIBLE BORON-ORGANO AND OTHER SIMILAR POLYMERS.  
INVESTIGATOR: L. E. Stout and D. F. Chamberlain  
CONTRACT: AF 33(038)-23299  
CONTRACTOR: Washington University  
ABSTRACT: Exploratory work on the preparation of organo-titanium and organo-boron compounds is described. Initial efforts were directed toward the synthesis of compounds of the type  $R_2Ti(OH)_2$  and  $RB(OH)_2$ . The work on titanium supports the evidence previously reported in the literature, that titanium-organoboron compounds, involving a Ti-C bond, cannot be formed.

Efforts to synthesize the boronic acids  $RB(OH)_2$  were moderately successful; of the alkyl derivatives, the propyl, butyl, and hexyl were isolated; of the aryl type, only the phenyl derivative was obtained. All proved to be heat and moisture sensitive, and no condition of temperature, concentration, time atmosphere, or catalyst could be found which would induce condensation polymerization to



Organo complexes of boron trifluoride and dihydroxyfluoroboric acid were formed. Heating of these complexes produced various reactions, primarily decomposition, but did not result in polymer formation.

Condensation polymers were formed from boric acid and various glycols, but all were low melting and water soluble. Polymers were also formed from various mixtures of glycerol, boric acid, and phthalic anhydride (or maleic anhydride, or fumaric acid). Again the polymers were low melting and water sensitive.

It is concluded that the boronic acids do not undergo condensation polymerization similar to the dihydroxy silicones, but decompose to boric acid or the anhydride. Further, when polymeric esters or amides containing boron are formed, the presence of the boron introduces extreme water sensitivity.

TR 52-197, Part 1 (Uncl)

October 1952

SUBJECT: SYNTHETIC RUBBERS FROM CARBON-FLUORINE COMPOUNDS.



INVESTIGATOR: W. H. Pearlson and N. W. Taylor  
CONTRACT: AF 33(038)-515  
CONTRACTOR: Minnesota Mining and Manufacturing Company  
ABSTRACT: Exploratory investigation into the preparation and properties of fluorinated polymers is described. New polymeric compositions of matter have been synthesized and screened with respect to their potentialities as suitable elastomers for use under extreme conditions of temperature in contact with various fuels and oils. The esters of unsaturated hydrocarbons acids with 1,1-dihydroperfluoroalkyl alcohols represent the most promising class of monomers investigated so far; certain of their polymers have received considerable attention because of their rubbery properties and exceptional resistance to swelling by non-fluorinated solvents, although their low temperature flexibility will probably require extension by plasticization. Fluorinated condensation-type polymers such as polyesters and polyamides do not appear promising as elastomers but may have potentialities as fibres, films or structural plastics. Extensive structure versus property correlations are not attempted but it is concluded that either side-chain or backbone fluorine in polymeric structures promotes resistance to swelling by common solvents; the former does not appear to affect low temperature properties as adversely as skeletal attachment. The possibility of constructing a better monomer than a fluoro-alkyl acrylate for development into a superior elastomer for specialized Air Force applications is still conceded for the field is relatively new and the number of known compounds small.

TR 52-197, Part 2 (Uncl)

August 1952

SUBJECT: SYNTHETIC RUBBERS FROM CARBON-FLUORINE COMPOUNDS.  
INVESTIGATOR: A. M. Borders  
CONTRACT: AF 33(038)-515  
CONTRACTOR: Minnesota Mining and Manufacturing Company  
ABSTRACT: Exploratory studies of the preparation and properties of fluorine-containing polymers are described. These syntheses and tests are directed to highly solvent resistant elastomers with the widest possible useful temperature range. New classes of materials include polymers of unsaturated and perfluoroalkyl esters, fluorine-containing alkoxyalkyl acrylates, and vinyl 1,1-dihydroperfluoroalkyl ethers, and copolymers of perfluoroacrylonitrile, and of perfluorobutadiene.

Polymers and copolymers of 1,1-dihydroperfluoroalkyl acrylates continue to exhibit the best balance of low temperature flexibility and resistance to aromatic hydrocarbon fluids. Improved curing systems and reinforcement studies of these rubbery acrylate polymers have permitted comparison with commercially available synthetic rubbers. These compounds have adequate mechanical properties for gasket performance and have exceptional resistance to swelling by many fuels and fluids of interest to the Air Force. Although reinforcement of the fluoroacrylate

homopolymers has not been possible, their butadiene copolymers have been reinforced to vulcanizates with tensile strengths in excess of 2,000 psi. Homopolymers and butadiene copolymers of the butyl and hexyl acrylates have been submitted or are being prepared for further evaluation by Wright Air Development Center.

The ultimate goal in low temperature flexibility has so far not been reached. At the request of the Wright Air Development Center increased emphasis will be given to fluorine-containing elastomers of improved high temperature resistance. Promising leads are described with perfluorobutadiene copolymers and with suitably vulcanized poly-1,1-dihydroperfluorobutyl acrylate.

TR 52-230 (Uncl)

September 1952

SUBJECT: FUEL CELL SEALANT COMPOUNDS.  
INVESTIGATOR: Earl H. Sorg, John F. McCarthy, Edward M. Fettes, and Joseph S. Jorczak  
CONTRACT: AF 33(038)-30523  
CONTRACTOR: Thiokol Corporation  
ABSTRACT: This work was undertaken by the Thiokol Corporation to develop integral fuel tank sealant compounds with improved low and high temperature properties, increased toughness and adhesion, and better resistance to jet fuels.

Experimental integral fuel tank sealant compounds were prepared in two-package mixes from hexamethylene dichloride/triglycol dichloride/formal and pentamethylene dichloride/formal polymers. Compared to a 'Thiokol' LP-2 base sealant, these experimental compounds displayed improved low temperature properties, equivalent toughness and adhesion to aluminum, somewhat better resistance to heat aging at 212°F, and slightly poorer resistance to swell in aromatic fuels.

Compounding studies with 'Thiokol' LP-2 yielded formulations with improved adhesion properties and heat aging resistance.

Development work on clear sealant compounds disclosed the possibility of preparing sealants of this type from combinations of epoxide resins and 'Thiokol' liquid polymers; however, considerably more investigation of this aspect is required.

#### SANDWICH CONSTRUCTION

TR 53-72 (Uncl)

March 1953

SUBJECT: FOAMED-IN-PLACE PLASTIC SANDWICH CONSTRUCTION, METAL FACED.

WADC TR 53-373

74

INVESTIGATOR: E. Duplaga and B. D. Raffel  
CONTRACT: AF 33(038)-22258  
CONTRACTOR: Goodyear Aircraft Corporation  
ABSTRACT: Control surfaces, such as tabs and ailerons, and helicopter rotor blades and hollow propellers are most efficient as light weight structures made with relatively thin skin construction. However, this procedure results in design difficulties in order to avoid oil canning and fatigue and vibration failures, which cannot always be eliminated. These problems, it was thought, could be solved by filling the cavities of these parts and structures with a low density core material bonded to the faces or skins to produce a light weight, strong, rigid surface as in sandwich construction. An investigation of a foamed-in-place alkyd-isocyanate resin system as a possible means to accomplish this task is described. Significant features discussed are the treatment of the aluminum skins along with the application of various coatings to achieve improved metal to foam bond. It is concluded that the sulfuric acid-sodium dichromate treatment of the metal produces the most effective cleaning of aluminum for coating preparation. The application of Epon VI as a coating for the aluminum improves the physical strength of the sandwich and minimizes the "cleavage plane" effect in the foam adjacent to the skin-core bond.

TR 52-51 (R)

June 1952

SUBJECT: FOAMED METAL LOW DENSITY CORE MATERIAL FOR SANDWICH CONSTRUCTION.  
INVESTIGATOR: J. Bjorksten, J. C. Elliott, and R. J. Roth  
CONTRACT: AF 33(038)-21838  
CONTRACTOR: Bjorksten Research Laboratories, Inc.  
ABSTRACT: Metallic low density foams were produced from magnesium-aluminum alloys using either titanium or zirconium hydride as the foaming agent.

The most effective procedure consisted of the prior preparation of a mixture of the hydride and the magnesium-aluminum eutectic alloy as the foaming agent. Incorporation of the melted foaming agent into the molten alloy to be foamed at a temperature slightly above its melting point produces a mixture, which on solidification is a satisfactory metallic foam.

By this procedure, a foam with a density of 15 pounds per cubic foot was obtained from the 95% Al-5% Mg alloy. This foam had a nominal cell size of about 1/16 inch. The cell size was quite uniform. More than 80% of the cells were 1/16" or less, 2% zirconium hydride was used to produce this foam.

TR 52-184 (Uncl)

December 1952

SUBJECT: SUMMARY OF RESEARCH BY FOREST PRODUCTS LABORATORY ON  
SANDWICH CONSTRUCTION FOR AIRCRAFT.  
INVESTIGATOR: Donald G. Coleman  
CONTRACT: AF 18(600)-70  
CONTRACTOR: Forest Products Laboratory  
ABSTRACT: Developments in the program of research in sandwich air-  
craft construction conducted by the U. S. Forest Products Laboratory are  
summarized. The approach has been in general to derive design criteria  
mathematically and then to check by test. Sixty-six technical reports  
issued during the several years this project has been under way are ab-  
stracted.

### TEXTILES

TR 53-21 (Uncl)

March 1953

SUBJECT: A STUDY ON THE EFFECT OF TEMPERATURE ON TEXTILE MATERIALS.  
INVESTIGATOR: Myron J. Coplan  
CONTRACT: AF 33(038)-22932  
CONTRACTOR: Fabric Research Laboratories  
ABSTRACT: Temperature requirements are of prime importance in the de-  
velopment of materials and equipment for the USAF. The use of parachutes  
to decelerate aircraft and recover missiles from high altitudes, brings  
forth the requirements for heat resistance, while operation in the Arctic  
and Antarctic regions sets the requirements for low temperature. With  
these requirements in mind, an investigation to study the effects of tem-  
perature and humidity on textile fibers was initiated. To make this in-  
vestigation as thorough as possible, all fibers, both natural and synthe-  
tic, which were available were included, with the exception of those  
fibers not thought feasible for parachute use, such as wool.

The yarns studied were broken down into two categories;  
filament and staple. The filament yarns were;

- a. Nylon
- b. Orlon
- c. Dacron
- d. Fortisan (Saponified Acetate)
- e. Tenasco (High Tenacity Viscose Rayon)
- f. Vinyon NORU, NOHU
- g. Japanese Gum Silk
- h. Fiberglas

The staple yarns used were;

- a. Acrilan
- b. Dynel

- c. Cotton, grieg
- d. Cotton, mercerized

The main objective of this investigation was to evaluate the fibers at temperatures from -70°F. to the extremely high temperatures, at which the fibers fail to function efficiently. (This temperature ranges from 300°F. to 375°F. as shown in the report.) To make the evaluation complete in itself, such properties of the yarns as average breaking tenacity, average breaking elongation, average yield tenacity, average initial modulus, average loop tenacity and efficiencies, energy absorbed to several stress levels, and heat shrinkage were obtained at various temperatures and after exposure for specific lengths of time at each temperature. Detailed data are given in both tabular and graphic form, as well as a discussion covering the mechanical behavior of fibers.

It is quite apparent from the tables and charts, that at and after exposure to temperatures of 350°F, Dacron yarn is superior in most of the properties studied. Most noticeable is the energy absorbed at various stress levels, loop tenacity and efficiency, and especially Dacron's resistance to hot air degradation.

TR 52-55 (Uncl)

March 1952

SUBJECT: A STUDY OF THE EFFECT OF TWIST ON THE PROPERTIES OF SYNTHETIC FILAMENT YARNS.  
INVESTIGATOR: J. C. Taylor, C. Y. Widequist, M. M. Christie, and V. R. Thompson  
CONTRACT: AF 33(038)-10179  
CONTRACTOR: Georgia Institute of Technology  
ABSTRACT: As synthetic textile fibers have varied uses in today's ideas and materials, a need has been felt for an investigation into the effect of twist on synthetic yarns. It was decided that in the study of synthetic yarns, those used most in USAF materials would be evaluated.

Yarns studied included five deniers of Viscose Rayon from three producers; ten deniers of nylon; four deniers of Orlon; and three deniers of Dacron. The main objective of the program was the study of the effect of twist on the following properties of the yarn:

- a. Denier
- b. Diameter
- c. Breaking strength
- d. Elongation

e. Energy Absorption

f. Elastic Recovery

Increments of twist were added to the yarns until the breaking strength had decreased approximately 40% from the original values, or until creeping or shearing occurred.

The twisting of the yarns and testing were conducted in laboratories conditioned to 70° plus or minus 2°F. and a Relative Humidity of 65 plus or minus 2%.

Each yarn has been considered separately in the evaluation, but with rayon yarns no separation was made for each different manufacturer's yarn. Generally the results show that the effect of twist on any characteristic of yarn is greater for the higher denier yarns than for the low denier yarns. Detailed data are given in both tabular and graphic form, for the effect of twist on the properties of the individual yarns.

TR 52-57 (Uncl)

December 1952

SUBJECT: INVESTIGATION OF IMPACT LOAD ABSORPTION THROUGH SUSPENSION LINE ELONGATION.  
INVESTIGATOR: E. A. Gimalouski  
CONTRACT: AF 33(038)-10401  
CONTRACTOR: Pioneer Parachute Company  
ABSTRACT: The purpose of this investigation was the study of suspension lines under actual operating conditions, having varying degrees of elongation, energy absorption and elasticity. A secondary purpose of the investigation was the study of fabric porosity, shape and type of canopy, and method of parachute deployment.

The shock absorbing capacity of five different types of parachute suspension line cord were first evaluated for basic physical properties, then were tested by assembling into parachutes and opening the parachute at various speeds - first at 100 mph, then 150 mph, finally 200 mph - on a whirling test tower. The parachutes were evaluated first in standard back type, then in deployment bag openings. Two types of parachutes were used; one being a twenty four foot standard parachute, the other being a 30 foot parachute, with an extended skirt.

The loads were measured and the cords evaluated on the basis of shock absorbing capacity, strength, and durability. Final results of the work indicates that the presently used 550 lb tensile strength cord, Specification MIL-C-5040, Type III, is the best of the cords evaluated. A good correlation was established between line energy absorption

and snatch force, but opening shock loads appear to be little affected by line characteristics.

TR 52-112 (Uncl)

July 1952

SUBJECT: DEVELOPMENT OF FABRICS FOR USAF SUMMER UNIFORMS USING SYNTHETIC FIBERS.

INVESTIGATOR: Rama Maxwell Ellis, Jr., 2/Lt.

ABSTRACT: This project was undertaken as a result of a letter from Headquarters USAF, dated 29 March 1951, entitled "Conservation of Wool", and because it was believed that synthetic fibers possessed an untapped potential adaptable to the needs of the USAF for uniform purposes.

"Dacron", a polyester fiber, was chosen as the principal constituent in this investigation because of its unusual properties. The manner in which this fiber would react when used in a uniform fabric and when blended with other fibers could not be determined by laboratory methods; hence the service wear test.

This service wear test was conducted during the months of July, August, September and October of the year 1951 at Wright-Patterson Air Force Base, Ohio, by the Textile Branch of the Materials Laboratory, Research Division, Wright Air Development Center. Forty-eight men participated in the test.

The results of this test indicate that Dacron, when blended with wool or viscose rayon in a fifty-to-fifty weight ratio, will produce a fabric superior to either the presently used 100% wool or the experimental 100% Dacron fabric.

TR 52-283, Part 1 (Uncl)

November 1952

SUBJECT: AIR PERMEABILITY OF PARACHUTE CLOTHS.

INVESTIGATOR: M. J. Goglia

CONTRACT: AF 33(038)-15624

CONTRACTOR: Georgia Institute of Technology

ABSTRACT: The air permeability of eight standard nylon parachute cloths was determined using a sample 6.05 inches in diameter in a wind tunnel whose capacity permitted obtaining static pressure differentials across the cloth as high as 55 inches of water. Fifty-nine experimental nylon cloths manufactured by the Bally Ribbon Mills were subjected to the same test procedure, as were two experimental fabrics of orlon and dacron, respectively.

Upon assuming that the pressure gradient in the flow through a parachute fabric is proportional to the arithmetic sum of an inertial ( $\beta \rho v^2$ ) and the viscous contribution ( $\alpha \mu v$ ), one is able to in-

fer the existence of a parameter,  $\beta/\alpha$  whose measure is length. This length can be employed to characterize the geometry of the cloth. Experimental work to date in the case of the eight standard cloths and the orlon and dacron fabrics has indicated a verification of the assumption; a high-pressure tunnel employing pressure differentials across the cloth approximately ten pounds per square inch was used for this purpose.

Employing the characteristic length so determined permits writing a single relation common to all cloths between a "flow-through-drag coefficient,"  $C_f$ , and a Reynolds number based on the characteristic length; viz.,  $C_f = 2 + \frac{2}{N_{Re}}$ .

TR 52-283, Part 2 (Uncl)

December 1952

SUBJECT: AIR PERMEABILITY OF PARACHUTE CLOTHS.  
INVESTIGATOR: H. W. S. Lavier  
CONTRACT: AF 33(038)-15624  
CONTRACTOR: Georgia Institute of Technology  
ABSTRACT: The air permeability of special, woven, nylon, orlon, and dacron, parachute-type fabrics was determined using a sample 6.05 inches in diameter. The permeometer used in this program permitted testing the fabric samples at pressure differentials across the cloth as high as 55 inches of water. The sixty-one experimental cloths woven in the Laboratories of the Georgia Institute of Technology Textile School were subject to this test procedure.

Air permeability data for the Georgia Tech-woven fabrics, Bally Ribbon cloths, and the ten Air Force-furnished fabrics are presented here in graphical form as volumetric flow (cubic feet per minute) versus static pressure differential across the cloth.

The number of ends per inch in warp, and picks per inch in the filling, and denier of yarns was found to affect air permeability of these fabrics. The finishing of the fabrics was found to affect the permeability more than any other of the many variables involved. The tests to determine the effect of variation of the weave pattern failed to show significant differences on this account.

#### TRANSPARENT MATERIALS

TR 52-292 (Uncl)

November 1952

SUBJECT: ELEVATED- AND ROOM-TEMPERATURE PROPERTIES OF SELECTRON 44 AND 5105XP TRANSPARENT PLASTIC SHEET MATERIALS.



INVESTIGATOR: John VanEcho, Gale R. Remely, and Ward F. Simmons  
CONTRACT: AF 33(038)-10818  
CONTRACTOR: Battelle Memorial Institute  
ABSTRACT: Two transparent plastic sheet materials, Selectron 44, a polyester, and 5105XP, an acrylate, were tested in tensile creep and creep rupture, crazing, short-time tensile, and deterioration at 80°, 160°, and 200°F. Additional short-time tensile tests were made at 250° and 300°F.

The creep and creep-rupture tests indicated that the 5105XP material had considerably more strength than Selectron 44 at all three test temperatures. The short-time tensile tests gave a similar indication at 80°, 160°, and 200°F, but at 250°F Selectron 44 appeared to have a slight superiority in strength. At 300°F, 5105XP had no practical load-carrying ability at all, while Selectron 44 showed a tensile strength of only 204 psi.

Selectron 44 displayed no crazing whatsoever at any temperature or strain rate. The crazing strength of 5105XP was, in general, equal to or greater than the rupture strength of Selectron 44 at all three test temperatures.

TR 52-38 (Uncl)

February 1952

SUBJECT: ELEVATED- AND ROOM- TEMPERATURE PROPERTIES OF TRANSPARENT ACRYLIC SHEET MATERIALS.  
INVESTIGATOR: John VanEcho, Gale R. Remely, and Ward F. Simmons  
CONTRACT: AF 33(038)-10818  
CONTRACTOR: Battelle Memorial Institute  
ABSTRACT: Two regular grades of transparent acrylic sheet, Plexiglas Ia and Lucite HC-201, and two heat-resistant grades, Lucite HC-202 and Plexiglas II, were tested in tensile creep and creep rupture, crazing, short-time tensile, and deterioration at room temperature, 160°, and 200°F.

The creep and creep-rupture tests indicated that the heat-resistant variety was considerably stronger than the regular grade, even at room temperature. At 160° and 200°F the superiority of the heat-resistant grade was much greater. At 200°F the regular acrylate sheet did not have any practical load-carrying ability.

The heat-resistant material was also much superior to the regular acrylate sheet in resistance to crazing at elevated temperatures. A linear relationship exists between temperature and stress for incipient crazing in the heat-resistant acrylate over the temperature range of this investigation. The stress to produce crazing decreased about 15 psi for each degree increase in temperature.

December 1952

SUBJECT: DEVELOPMENT OF HEAT-RESISTANT INTERLAYER MATERIALS FOR LAMINATED GLASS.

INVESTIGATOR: Johan Bjorksten, Luther L. Yaeger, and Robert J. Roth

CONTRACT: AF 33(038)-16240

CONTRACTOR: Bjorksten Research Laboratories, Inc.

ABSTRACT: Of the various materials investigated, Mylar (duPont poly ethylene glycol terephthalate) was the most effective heat resistant interlayer for aircraft laminated glass. It withstands 400°F. for as long as two hours without apparent deleterious effects. Mylar-glass laminates maintain their shatter resistance throughout the temperature range of -65° to 400°F. and under differential pressures and temperature gradients simulating flight conditions.

Other polymers, which were not as satisfactory as Mylar because of insufficient thermal stability and/or poor optical properties, included:

Cross-linked polyvinylbutyral  
Alcohol soluble polyamid (Nylon, type 8)  
Silicone elastomer  
Chlorofluoro polymer (Kel F)

Epoxy type adhesives produced the best bonding between Mylar and glass.

In view of the developmental nature of this work, these conclusions must be regarded as tentative and subject to further investigation. Further work on Mylar interlayers for glass laminates is being performed under Contract No. AF 33(600)-22723.

TR 6629, Section 2 (Uncl)

September 1952

SUBJECT: RESISTANCE TO SHATTERING BY GUNFIRE OF TRANSPARENT LAMINATED MATERIALS FOR AIRCRAFT GLAZING.

INVESTIGATOR: E. M. Petruska

CONTRACT: AF 33(038)-23269

CONTRACTOR: Rohm and Haas Company

ABSTRACT: Two-hundred-thirty-nine (239) acrylic-butyral laminates have been tested under uniform conditions. These included seven configurations of both Plexiglas II and Lucite HC-202, supplied by two laminators, Pittsburgh Plate Glass Co. and Glass Products Division of American Window Glass Co.

SECTION II  
TECHNICAL REPORTS

Prior to 1 July 1951

ACCESSORIES, AIRCRAFT

TR 4720 (Uncl) November 1945

SUBJECT: MECHANICAL PROPERTIES OF SEAMLESS TUBING OF 5% ZINC-COPPER-MAGNESIUM ALUMINUM ALLOY.

INVESTIGATOR: R. T. Schwartz, D. A. Shinn, and T. T. Oberg

TR 4938 (Uncl) May 1943

SUBJECT: INVESTIGATION OF THE TENDENCY OF TURNBUCKLE AIRCRAFT CABLE ASSEMBLIES TO UNSCREW UNDER LOAD.

INVESTIGATOR: David M. Warner, Maj., and Wilbur Gross

TR 5064 (Uncl) December 1943

SUBJECT: THE EFFECT OF CONTROLLED ALUMINUM RIVET HEAD DIAMETER UPON THE STATIC SHEAR AND TENSILE STRENGTH IN THIN ALCLAD 24S-T SHEET.

INVESTIGATOR: Edward Dugger and H. W. Sedam

TR 5563 (Uncl) March 1947

SUBJECT: HIGH EXPANSION STEEL CONTROL CABLE.

INVESTIGATOR: Edward Dugger and H. W. Sedam

TR 5651 (Uncl) December 1947

SUBJECT: ENDURANCE CHARACTERISTICS OF STANDARD AIRCRAFT CONTROL PULLEYS.

INVESTIGATOR: Edward Dugger and William Randolph

TR 5599 (Uncl) June 1947

SUBJECT: TENSILE APPLICATOR FOR AIRCRAFT BOLTS.

INVESTIGATOR: Harry W. Sedam

ADHESIVES, STRUCTURAL

TR 5896, Part 1 (Uncl) July 1949

SUBJECT: HIGH TEMPERATURE METAL TO METAL ADHESIVES.

INVESTIGATOR: P. M. Elliott and W. C. Imholz  
CONTRACT: W33-038-ac-20810  
CONTRACTOR: United States Rubber Company

TR 5928 (Uncl)

August 1949

SUBJECT: GLUING TESTS WITH ROOM-TEMPERATURE-SETTING ADHESIVES TO  
FABRIC-BASE PLASTIC LAMINATES.

INVESTIGATOR: Herbert W. Eickner

CONTRACT: P.O. (33-038)-47-359  
P.O. (33-038)-47-2902-E  
P.O. (33-038)-48-11  
P.O. (33-038)-49-180

CONTRACTOR: Forest Products Laboratory

AIRCRAFT PARTS

TR 5219 (Uncl)

March 1945

SUBJECT: METALLURGICAL INVESTIGATION OF THE COMPONENTS OF THE JUMO  
004 JET PROPULSION ENGINE DESIGNED FOR THE MESSERSCHMITT  
262 AIRPLANE.

INVESTIGATOR: Louis A. Priolo, Capt.

TR 5496 (Uncl)

May 1946

SUBJECT: METALLURGICAL STUDY OF AIRCRAFT ENGINE VALVES.

INVESTIGATOR: Isaac Perlmutter

ALLOYS, FERROUS

TR 4773 (Uncl)

May 1942

SUBJECT: VARIATION IN PROPERTIES OF COLD-ROLLED CORROSION-RESISTANT  
18-8 STEEL SHEET AND EFFECTS OF LOW TEMPERATURE HEAT TREAT-  
MENT.

INVESTIGATOR: B. Chasman, G. M. Martell, and T. T. Oberg

TR 4799, Part 1 (Uncl)

July 1942

SUBJECT: INVESTIGATION OF ALTERNATE STEELS.

INVESTIGATOR: A. C. Willis, 2/Lt., and Morse Hill

TR 4799, Part 2 (Uncl)

December 1942

SUBJECT: INVESTIGATION OF ALTERNATE STEELS.

INVESTIGATOR: Morse Hill

WADC TR 53-373

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TR 4802 (Uncl)

July 1942

SUBJECT: HARDENABILITY OF STEEL.  
INVESTIGATOR: Morse Hill

TR 5645 (Uncl)

October 1947

SUBJECT: STUDY OF THE METALLURGICAL CHARACTERISTICS OF THREE INDUCTION-HARDENED STEELS HEATED AT VARIOUS RATES.  
INVESTIGATOR: James W. Poynter

TR 5657 (Uncl)

January 1948

SUBJECT: THE EFFECT OF OVERSTRESS IN FATIGUE ON THE ENDURANCE LIFE OF SAE 4340 STEEL.  
INVESTIGATOR: Ture T. Oberg

TR 5696 (Uncl)

April 1948

SUBJECT: DETERMINATION OF HARDENABILITY OF LOW ALLOY STEELS.  
INVESTIGATOR: James W. Poynter

ALLOYS, HIGH TEMPERATURE

TR 5435 (Uncl)

March 1946

SUBJECT: COMPARISON OF HIGH TEMPERATURE PROPERTIES OF TURBINE WHEEL ALLOYS OF LOW ALLOY CONTENT.  
INVESTIGATOR: Isaac Perlmutter

TR 5649 (Uncl)

November 1947

SUBJECT: STRESS CORROSION OF HEAT RESISTANT ALLOYS AT ELEVATED TEMPERATURES.  
INVESTIGATOR: Isaac Perlmutter

TR 5712 (Uncl)

July 1948

SUBJECT: INVESTIGATION OF SHEET MATERIALS FOR APPLICATION AT HIGH TEMPERATURES.  
INVESTIGATOR: Isaac Perlmutter and W. H. Rector

TR 5716 (R)

July 1948

SUBJECT: SERVICE FAILURE OF TURBINE BUCKETS.  
INVESTIGATOR: Isaac Perlmutter and H. K. Adenstedt

TR 5730 (Uncl)

November 1948

SUBJECT: RESEARCH ON HIGH TEMPERATURE SHEET MATERIAL.  
INVESTIGATOR: William Murphy and L. L. Ferrall  
CONTRACT: W33-038-ac-16677  
CONTRACTOR: Crucible Steel Company of America

TR 5731 (Uncl)

November 1948

SUBJECT: THE DEVELOPMENT OF SHEET MATERIALS FOR HIGH TEMPERATURE APPLICATIONS.  
INVESTIGATOR: Gunther Mohling and Joseph B. Meierdirks  
CONTRACT: W33-038-ac-16519  
CONTRACTOR: Allegheny Ludlum Steel Corporation

TR 5893 (Uncl)

July 1949

SUBJECT: INVESTIGATION OF THE STRESS RUPTURE PROPERTIES AT 1500°F OF A NUMBER OF HIGH TEMPERATURE ALLOYS.  
INVESTIGATOR: Melvin E. Fields, Capt., and William H. Rector

TR 5929 (Uncl)

June 1949

SUBJECT: UTILIZATION OF LOW ALLOY MATERIALS FOR HIGH TEMPERATURE SERVICE APPLICATIONS.  
INVESTIGATOR: James Miller, L. W. Smith, and Phillip K. Porter  
CONTRACT: W33-038-ac-21094  
CONTRACTOR: Cornell Aeronautical Laboratory, Inc.

TR 5930 (Uncl)

February 1950

SUBJECT: DYNAMIC CREEP AND RUPTURE PROPERTIES OF TEMPERATURE RESISTANT MATERIALS UNDER TENSILE FATIGUE STRESS.  
INVESTIGATOR: B. J. Iazan  
CONTRACT: W33-038-ac-15941(17507)  
CONTRACTOR: Syracuse University

TR 5936, Part 1

May 1950

SUBJECT: ELEVATED TEMPERATURE FATIGUE TESTING OF TURBINE BUCKETS. PART 1 - CALCULATIONS OF NATURAL FREQUENCIES AND STRESSES, AND PROPOSED TESTING METHODS.  
INVESTIGATOR: A. Herzog, Dr.

TR 5949 (Uncl)

May 1950

SUBJECT: U-36 ALLOY DETERMINATION OF DESIGN DATA.  
INVESTIGATOR: Ward F. Simmons

WADC TR 53-373

CONTRACT: AF 33(038)-956  
CONTRACTOR: Battelle Memorial Institute

TR 6188 (Uncl)

July 1950

SUBJECT: STRESS RUPTURE TESTS ON SHEET ALLOYS FOR HIGH TEMPERATURE APPLICATIONS.

INVESTIGATOR: Isaac Perlmutter

TR 6219 (Uncl)

October 1950

SUBJECT: FORGING BUCKET ALLOYS AND CAST BUCKET ALLOYS.

INVESTIGATOR: Gunther H. Mohling

CONTRACT: AF 33(038)-2040

CONTRACTOR: Allegheny Ludlum Steel Corporation

ALLOYS, NONFERROUS

TR 4531 (Uncl)

May 1940

SUBJECT: PROPERTIES OF X74S ALUMINUM ALLOY SHEET.

INVESTIGATOR: James W. Poynter

TR 4547 (Uncl)

June 1940

SUBJECT: EFFECTS OF ARTIFICIAL AGING ON THE PROPERTIES OF ALUMINUM ALLOY TUBING.

INVESTIGATOR: D. A. Shinn and W. G. Ramke

TR 4551 (Uncl)

July 1940

SUBJECT: STUDY OF THE MECHANICAL PROPERTIES AND BEHAVIOR ON HEAT-TREATMENT OF A HIGH STRENGTH ALUMINUM BASE FORGING ALLOY.

INVESTIGATOR: James W. Poynter

TR 4560 (Uncl)

August 1940

SUBJECT: MECHANICAL PROPERTIES OF VARIOUS ALUMINUM ALLOY FORGINGS.

INVESTIGATOR: N. B. Frank and Ture T. Oberg

TR 4566 (Uncl)

October 1940

SUBJECT: DETERMINATION OF INTERNAL STRESSES IN ALUMINUM ALLOY PLATES.

INVESTIGATOR: R. T. Schwartz

TR 4902 (Uncl)

April 1943

SUBJECT: PROPERTIES OF XA75S-T ALUMINUM ALLOY.

INVESTIGATOR: S. J. Broderick

WADC TR 53-373

TR 4902, Addendum 1 (Uncl)

November 1943

SUBJECT: PROPERTIES OF KA75S-T ALUMINUM ALLOY.  
INVESTIGATOR: S. J. Broderick and Ture T. Oberg

TR 5103 (Uncl)

March 1944

SUBJECT: EFFECT OF ARTIFICIAL AGING AND PRE-STRETCHING ON THE  
PROPERTIES OF ALCLAD 24S-T ALUMINUM ALLOY.  
INVESTIGATOR: S. J. Broderick

TR 5111 (Uncl)

May 1944

SUBJECT: INVESTIGATION OF R-301 CLAD ALUMINUM ALLOY SHEET.  
INVESTIGATOR: Baxter C. Madden, Major

TR 5129 (Uncl)

July 1944

SUBJECT: PROPERTIES OF ALCLAD XB75S SHEET.  
INVESTIGATOR: Richard R. Kennedy

TR 5187 (Uncl)

January 1945

SUBJECT: EXAMINATION OF PARALUMIN "2" ALLOY.  
INVESTIGATOR: William Courter, Pvt.

TR 5228 (Uncl)

March 1945

SUBJECT: ALUMINUM ALLOY AIRCRAFT EXTRUSIONS.  
INVESTIGATOR: Donald A. Shinn and Ture T. Oberg

TR 5357 (Uncl)

November 1945

SUBJECT: PROPERTIES OF R303 ALUMINUM ALLOY SHEET.  
INVESTIGATOR: Gustavus S. Simpson, Jr., 1/Lt.

TR 5589 (Uncl)

June 1947

SUBJECT: AGE HARDENING HEAT TREATMENT OF 75S-T AND R303 ALUMINUM  
ALLOY SHEET MATERIALS.  
INVESTIGATOR: James J. Niehaus

TR 5603 (Uncl)

June 1947

SUBJECT: DEVELOPMENT OF ML ALUMINUM ALLOY FOR ELEVATED TEMPERATURE  
SERVICE.  
INVESTIGATOR: J. C. McGee



TR 5694 (Uncl)

April 1948

SUBJECT: TENSION-COMPRESSION BIAxIAL PLASTIC STRESS-STRAIN RELATIONS  
FOR ALCOA 24S-T.  
INVESTIGATOR: Joseph Marin, J. H. Faupel, and V. L. Dutton  
CONTRACT: W33-038-ac-15934  
CONTRACTOR: Pennsylvania State College

TR 5701 (Uncl)

May 1948

SUBJECT: STATIC AND FATIGUE TESTS OF CAST AND FORGED I-BEAMS OF  
ALUMINUM AND MAGNESIUM ALLOYS.  
INVESTIGATOR: Ture T. Oberg and R. J. Rooney

TR 5945 (Uncl)

May 1950

SUBJECT: 75S-T6 ALUMINUM ALLOY - SOME BENDING AND DISTORTION CHARAC-  
TERISTICS.  
INVESTIGATOR: J. C. McGee

TR 4556 (Uncl)

July 1940

SUBJECT: CORROSION RESISTANCE OF MAGNESIUM ALLOY SHEET IN CONTACT WITH  
DISSIMILAR METALS.  
INVESTIGATOR: M. R. Whitmore

TR 4725 (Uncl)

January 1942

SUBJECT: MECHANICAL PROPERTIES OF MAGNESIUM ALLOY TUBING.  
INVESTIGATOR: G. M. Martell

TR 4780 (Uncl)

May 1942

SUBJECT: PROPERTIES OF MAGNESIUM CASTING ALLOYS.  
INVESTIGATOR: J. L. Gregg and S. J. Broderick

TR 5156 (Uncl)

October 1944

SUBJECT: MAGNESIUM ALLOYS. PROPERTIES AND AIRCRAFT APPLICATIONS.  
INVESTIGATOR: J. B. Cahan and P. W. Bakarian

TR 5246 (Uncl)

July 1945

SUBJECT: FOUNDRY PROCEDURES AND TEST DATA OF THE WRIGHT FIELD MAG-  
NESIUM FOUNDRY.  
INVESTIGATOR: John J. Casey, Capt.

WADC TR 53-373

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TR 5349 (Uncl)

November 1945

SUBJECT: SUSCEPTIBILITY OF FOUR MAGNESIUM CASTING ALLOYS TO MICRO-POROSITY AND ITS EFFECT ON THE MECHANICAL PROPERTIES.  
INVESTIGATOR: Jay R. Burns, S/Sgt.

TR 5517 (Uncl)

August 1946

SUBJECT: SOME COMPARATIVE FOUNDED AND CORROSION PROPERTIES OF AZ63, AZ92, A8 and AZ91 MAGNESIUM CASTING ALLOYS.  
INVESTIGATOR: Jay R. Burns, J. J. Casey, and Wilford Dent

TR 5734 (Uncl)

November 1948

SUBJECT: NEW MAGNESIUM ALLOYS.  
INVESTIGATOR: A. Jones, R. D. Malin, and R. R. Nash  
CONTRACT: W33-038-ac-16541(17401)  
CONTRACTOR: Rensselaer Polytechnic Institute

TR 5755 (Uncl)

November 1948

SUBJECT: MAGNESIUM-ZINC BASE CASTING ALLOYS.  
INVESTIGATOR: Jay R. Burns

TR 6173 (Uncl)

June 1950

SUBJECT: MAGNESIUM ALLOYS CONTAINING ZIRCONIUM.  
INVESTIGATOR: G. W. Orton, 1/Lt.

TR 6174 (Uncl)

June 1950

SUBJECT: MAGNESIUM ALLOY RESEARCH. TERNARY MAGNESIUM-LITHIUM BASE CONSTITUTION DIAGRAMS. MAGNESIUM ALLOYS OF LOW ALLOY ADDITIONS. PREPARATION OF SINGLE CRYSTALS OF MAGNESIUM ALLOYS.

INVESTIGATOR: A. Jones, R. R. Nash, R. G. Brown, and W. P. James  
CONTRACT: W33-038-ac-22542  
CONTRACTOR: Rensselaer Polytechnic Institute

TR 6383 (Uncl)

June 1951

SUBJECT: RESEARCH ON THE ELEMENT SILICON AND SILICON ALLOYS.  
INVESTIGATOR: W. R. Johnson and M. Hansen  
CONTRACT: AF 33(038)-8517  
CONTRACTOR: Armour Research Foundation, Illinois Institute of Technology

TR 5732 (Uncl)

November 1948

SUBJECT: INVESTIGATION OF CHROMIUM-TITANIUM BINARY ALLOYS.  
INVESTIGATOR: Dr. M. G. Fontana  
CONTRACT: W33-038-ac-16368  
CONTRACTOR: Ohio State University Research Foundation

TR 5935 (Uncl)

February 1950

SUBJECT: MECHANICAL PROPERTIES, WELDABILITY AND CORROSION OF COMMER-  
Cially PURE TITANIUM.  
INVESTIGATOR: Dr. H. K. Adenstedt

TR 5946 (Uncl)

May 1950

SUBJECT: TITANIUM-CHROMIUM BINARY ALLOYS.  
INVESTIGATOR: Dr. M. G. Fontana  
CONTRACT: W33-038-ac-21339(20377)  
CONTRACTOR: Ohio State University Research Foundation

TR 6218, Part 2 (Uncl)

June 1950

SUBJECT: RESEARCH AND DEVELOPMENT ON TITANIUM ALLOYS.  
INVESTIGATOR: L. W. Eastwood and C. H. Lorig  
CONTRACT: AF 33(038)-3736  
CONTRACTOR: Battelle Memorial Institute

TR 6516, Part 1 (Uncl)

June 1951

SUBJECT: THE TITANIUM-MANGANESE, TITANIUM-TUNGSTEN, AND TITANIUM-  
TANTALUM PHASE DIAGRAMS.  
INVESTIGATOR: R. I. Joffe, L. W. Eastwood, and D. J. Maykuth  
CONTRACT: AF 33(038)-8544  
CONTRACTOR: Battelle Memorial Institute

TR 5932 (Uncl)

June 1949

SUBJECT: ZIRCONIUM ALLOYS FOR HIGH TEMPERATURE SERVICE.  
INVESTIGATOR: Stephen M. Shelton  
CONTRACT: W33-038-47-4493-E  
CONTRACTOR: United States Bureau of Mines

TR 5943 (Uncl)

March 1950

SUBJECT: RESEARCH ON ZIRCONIUM ALLOYS.  
INVESTIGATOR: Felix B. Litton and S. C. Ogburn, Jr.

CONTRACT: W33-308-ac-20168  
CONTRACTOR: Foote Mineral Company

ANALYSIS AND MEASUREMENT

TR 4596 (Uncl) December 1940  
SUBJECT: SPECTROGRAPHIC METHOD FOR THE DETERMINATION OF IRON IN  
MAGNESIUM ALLOYS.  
INVESTIGATOR: C. B. Pittinger, Jr.

TR 4617, Addendum 1 (Uncl) January 1943  
SUBJECT: DEVELOPMENT OF GLOSS SPECIFICATION FOR CAMOFLAGE FINISHES.  
ADDENDUM 1 - MEASUREMENT OF SPECULAR GLOSS.  
INVESTIGATOR: Harry Schechter

TR 4995 (Uncl) August 1943  
SUBJECT: DEVELOPMENT OF SPECTROPHOTOMETRIC PROCEDURES.  
INVESTIGATOR: E. H. Young

TR 5014 (Uncl) September 1943  
SUBJECT: LABORATORY MANUAL FOR ORGANIC SYNTHETIC PLASTICS.  
INVESTIGATOR: E. J. Fischer (1937) and Leah K. Hendriksen, Translator

TR 5628 (Uncl) August 1947  
SUBJECT: METHOD OF SPECTROGRAPHIC ANALYSIS FOR BERYLLIUM IN MAG-  
NESIUM ALLOYS.  
INVESTIGATOR: Robert E. Brocklehurst

TR 6189 (Uncl) July 1950  
SUBJECT: THERMAL CONDUCTANCES OF JET ENGINE BLANKETS. METHOD FOR  
DETERMINATION ABOVE 1200°F.  
INVESTIGATOR: L. F. Salzberg

BIOCHEMISTRY

TR 5588 (Uncl) May 1947  
SUBJECT: FUNGUS RESISTANCE OF RUBBER CORK COMPOSITION TAPE SPECI-  
FICATION 12023.  
INVESTIGATOR: Francis Czarnecki, Pfc.

CERAMICS

TR 5897 (Uncl)

June 1949

SUBJECT: THE PROTECTIVE COATING OF MOLYBDENUM.  
INVESTIGATOR: A. M. Suggs  
CONTRACT: W33-038-ac-19697  
CONTRACTOR: P. R. Mallory and Company, Inc.

TR 5947 (Uncl)

May 1950

SUBJECT: MANUFACTURE OF METAL-CERAMIC COMBINATIONS.  
INVESTIGATOR: E. F. Swazy  
CONTRACT: W33-038-ac-19697  
CONTRACTOR: P. R. Mallory and Company, Inc.

TR 6512 (Uncl)

April 1951

SUBJECT: MECHANICAL PROPERTY TESTS ON CERAMIC BODIES.  
INVESTIGATOR: W. H. Duckworth, A. D. Schwope, and J. K. Johnston  
CONTRACT: AF 33(038)-8682  
CONTRACTOR: Battelle Memorial Institute

TR 6218, Part 1 (Uncl)

June 1950

SUBJECT: REFRACTORIES FOR MELTING TITANIUM.  
INVESTIGATOR: L. W. Eastwood and C. M. Craighead  
CONTRACT: W33-038-ac-21229  
CONTRACTOR: Battelle Memorial Institute

TR 6515 (Uncl)

May 1951

SUBJECT: IMPREGNATION OF CARBIDE SKELETAL BODIES WITH SELECTED METALS OR ALLOYS.  
INVESTIGATOR: Earle T. Montgomery, Thomas S. Shelvin, and Clinton C. McBride  
CONTRACT: AF 33(038)-6841  
CONTRACTOR: Ohio State University Research Foundation

TR 6601, Part 1 (Uncl)

March 1951

SUBJECT: AN INVESTIGATION OF THE ALLOYS OF ALUMINUM AND MOLYBDENUM.  
INVESTIGATOR: R. L. Wachtell  
CONTRACT: AF 33(038)-10716  
CONTRACTOR: American Electro Metal Corporation

CLEANING

TR 4609 (Uncl)

February 1941

SUBJECT: INVESTIGATION OF AIRCRAFT CLEANING COMPOUNDS.  
INVESTIGATOR: Howard Packer

COATINGS

TR 4617 (Uncl)

March 1941

SUBJECT: DEVELOPMENT OF GLOSS SPECIFICATION FOR CAMOUFLAGE FINISHES.  
INVESTIGATOR: Harry Schechter

TR 5700 (Uncl)

May 1948

SUBJECT: EVALUATION OF THE CONDITION OF DOPED FABRIC SURFACE BY THE  
MULLEN BURST STRENGTH TEST AND OTHER METHODS.  
INVESTIGATOR: Elmer E. Jukkola

TR 5700, Supplement 1 (Uncl)

July 1949

SUBJECT: EVALUATION OF THE CONDITION OF DOPED FABRIC SURFACE BY THE  
MULLEN BURST STRENGTH TEST AND OTHER METHODS.  
INVESTIGATOR: Elmer E. Jukkola

TR 5700, Supplement 2 (Uncl)

July 1950

SUBJECT: EVALUATION OF THE CONDITION OF DOPED FABRIC SURFACE BY THE  
MULLEN BURST STRENGTH TEST AND OTHER METHODS.  
INVESTIGATOR: Elmer E. Jukkola

CORROSION

TR 5690 (Uncl)

April 1948

SUBJECT: REPRODUCIBILITY OF HUMIDITY EXPOSURE TESTS.  
INVESTIGATOR: Lewis E. Michael  
CONTRACT: W33-038-ac-14160  
CONTRACTOR: Battelle Memorial Institute

CRITERIA, DESIGN

TR 5144, Part 1 (Uncl)

September 1944

SUBJECT: INVESTIGATION OF STRESS CORROSION. PART 1 - TEST METHODS  
AND PROGRESS.

INVESTIGATOR: Baxter C. Madden, Major

TR 5144, Part 2 (Uncl)

October 1946

SUBJECT: INVESTIGATION OF STRESS CORROSION. PART 2 - RESULTS OF TESTS AND CONCLUSIONS INCLUDING A METHOD OF EVALUATING STRESS CORROSION SENSITIVITY.

INVESTIGATOR: Baxter C. Madden, Major

TR 5311 (Uncl)

October 1945

SUBJECT: METHOD OF TESTING THIN SHEET MATERIAL IN COMPRESSION.

INVESTIGATOR: Baxter C. Madden, Major

TR 5521 (Uncl)

August 1946

SUBJECT: METHOD OF TENSILE TESTING AT ELEVATED TEMPERATURES (200°F - 600°F.)

INVESTIGATOR: Baxter C. Madden, Major and E. L. Horne

TR 5662, Part 1 (Uncl)

January 1948

SUBJECT: INVESTIGATION OF MECHANICAL PROPERTIES AND PHYSICAL METALLURGY OF AIRCRAFT ALLOYS AT VERY LOW TEMPERATURES. PART 1 - IMPACT AND HARDNESS DATA OF SEVERAL AIRCRAFT METALS AT LOW-TEMPERATURES.

INVESTIGATOR: Donald A. Shinn

TR 5742, Part 1 and 2 (Uncl)

December 1948

SUBJECT: RAPID LOADING PROPERTIES OF AIRCRAFT STRUCTURAL METALS. PART 1 - DESIGN AND CONSTRUCTION OF A HYDRO-PNEUMATIC MACHINE FOR RAPID LOAD TENSILE TESTING. PART 2 - INFLUENCE OF RAPID LOAD AND TIME AT LOAD ON THE TENSILE PROPERTIES OF SEVERAL ALLOYS.

INVESTIGATOR: D. S. Wood, D. A. Elmer, and D. S. Clark

CONTRACT: W33-038-ac-14102(15772)

CONTRACTOR: California Institute of Technology

TR 5899 (Uncl)

August 1949

SUBJECT: TENSILE PROPERTIES OF SOME AIRCRAFT STRUCTURAL MATERIALS AT VARIOUS RATES OF LOADING.

INVESTIGATOR: Richard F. Klinger

#### ELECTRODEPOSITION

TR 5125 (Uncl)

July 1944

SUBJECT: FATIGUE LIMIT OF CHROMIUM PLATED STEEL.  
INVESTIGATOR: Louis Mehr, 1/Lt., Ture T. Oberg, and J. Teres, Captain

TR 5692 (Uncl)

April 1948

SUBJECT: AN INVESTIGATION OF ELECTRODEPOSITED ALLOYS AND PURE METALS  
AS SUBSTITUTES FOR ZINC AND CADMIUM FOR PROTECTIVE FINISHES  
FOR STEEL PARTS OF AIRCRAFT.

INVESTIGATOR: C. A. Snavely, A. B. Tripler, and C. L. Faust

CONTRACT: W33-038-ac-15723(16940)

CONTRACTOR: Battelle Memorial Institute

TR 5692, Supplement 1 (Uncl)

September 1949

SUBJECT: INVESTIGATION OF ELECTRODEPOSITED ALLOYS AND PURE METALS  
AS SUBSTITUTES FOR ZINC AND CADMIUM FOR PROTECTIVE FINISHES  
FOR STEEL PARTS OF AIRCRAFT.

INVESTIGATOR: A. B. Tripler and C. L. Faust

CONTRACT: W33-038-ac-21107(20145)

CONTRACTOR: Battelle Memorial Institute

### FATIGUE

TR 5623 (Uncl)

August 1947

SUBJECT: SIX TON SCHENCK FATIGUE TESTING MACHINE.

INVESTIGATOR: A. J. Herzog, Dr., Ing.

TR 5726, Parts 1 and 2 (In one volume) (Uncl)

October 1948

#### PART 1

SUBJECT: THE EFFECT OF SIZE AND NOTCH SENSITIVITY ON FATIGUE CHARAC-  
TERISTICS OF TWO METALLIC MATERIALS. PART 1 - ALUMINUM ALLOY  
75S-T.

INVESTIGATOR: H. F. Moore

CONTRACT: W33-038-ac-9225(1482)

CONTRACTOR: University of Illinois

#### PART 2

SUBJECT: THE EFFECT OF SIZE AND NOTCH SENSITIVITY ON FATIGUE CHARAC-  
TERISTICS OF TWO METALLIC MATERIALS. PART 2 - SAE 4340 STEEL.

INVESTIGATOR: T. J. Dolan and B. C. Hanley

CONTRACT: W33-038-ac-14712(16159)

CONTRACTOR: University of Illinois



TR 5775, Parts 1 and 2 (Uncl)

July 1949

SUBJECT: REVERSED BENDING FATIGUE CHARACTERISTICS OF STEEL AND HIGH  
STRENGTH ALUMINUM ALLOYS AS AFFECTED BY TYPE OF SPECIMEN.  
PART 1 - EXTRUDED ALUMINUM ALLOYS AND ROLLED 4130 STEEL PLATE.  
PART 2 - ALUMINUM ALLOY 75S-T6 PLATE.  
INVESTIGATOR: Ture T. Oberg and Robert J. Rooney

JOINING

TR 4423 (Uncl)

December 1938

SUBJECT: SPOT WELDING OF ALUMINUM ALLOYS.  
INVESTIGATOR: R. E. Bowman and J. B. Johnson

TR 4554 (Uncl)

July 1940

SUBJECT: TESTS OF SCIAKY PMCO. 2S SPOT WELDER.  
INVESTIGATOR: R. E. Bowman and R. W. Ego

TR 4657 (Uncl)

July 1941

SUBJECT: TESTS OF TAYLOR-WINFIELD HI-WAVE SPOTWELDER.  
INVESTIGATOR: R. E. Bowman and R. W. Ego

TR 4659 (Uncl)

July 1941

SUBJECT: SHUNT FOR THE MEASUREMENT OF WELDING CURRENT IN SPOT WELDERS.  
INVESTIGATOR: R. E. Bowman and R. W. Ego

TR 5310 (Uncl)

October 1945

SUBJECT: FLASH WELDED CENTRIFUGAL CASTINGS FOR AIRCRAFT.  
INVESTIGATOR: Edward L. Horne, Ture T. Oberg, and L. W. Katz, 1/Lt.

TR 5749 (Uncl)

January 1949

SUBJECT: TESTS AND EXAMINATION OF GAS PRESSURE WELDS.  
INVESTIGATOR: Robert E. Bowman, Walter Trapp, and C. B. Hartley

TR 5931 (Uncl)

September 1949

SUBJECT: DETERMINATION OF IMPURITIES IN INERT GASES.  
INVESTIGATOR: R. E. Bowman and C. B. Hartley

METALS, GENERAL

TR 4796 (Uncl)

July 1942

SUBJECT: AIRCRAFT QUALITY CASTING STANDARDS.  
INVESTIGATOR: Robert Katz

TR 4814 (Uncl)

August 1942

SUBJECT: STUDY OF MATERIALS USED IN AIR FRAME OF JUNKERS 88 AIRPLANE.  
INVESTIGATOR: Morse Hill

TR 5925 (Uncl)

September 1949

SUBJECT: PROCEDURES USED IN PRECISION CASTING FOUNDRY.  
INVESTIGATOR: William F. Davenport, 1/Lt. and Adolph Strott

TR 6191 (Uncl)

August 1950

SUBJECT: PRECOAT MATERIALS FOR INVESTMENT CASTING.  
INVESTIGATOR: William F. Davenport, 1/Lt. and Adolph Strott

TR 6222 (Uncl)

October 1950

SUBJECT: STUDY OF INVESTMENTS FOR PRECISION CASTING PROCESS.  
INVESTIGATOR: William F. Davenport, 1/Lt. and Adolph Strott

PETROLEUM PRODUCTS, FUELS

TR 5636 (Uncl)

September 1947

SUBJECT: STORAGE CHARACTERISTICS OF FUELS UNDER SEVERE AND MODERATE  
CLIMATIC STORAGE CONDITIONS.  
INVESTIGATOR: Robert W. Altman

TR 5895 (R)

July 1949

SUBJECT: THE INFLAMMABILITY CHARACTERISTICS OF LIQUID FUELS.  
INVESTIGATOR: L. T. Taylor, Captain

TR 5944 (Uncl)

May 1950

SUBJECT: ANALYTICAL METHODS FOR DETERMINING SOLUBILITY OF WATER IN  
HYDROCARBONS.  
INVESTIGATOR: Bernard Rubin and Robert J. Burger

PETROLEUM PRODUCTS, HYDRAULIC FLUIDS

TR 5561 (R)

March 1947

SUBJECT: HYDRAULIC FLUIDS, LUBRICANTS, FUELS AND RELATED MATERIALS.  
INVESTIGATOR: Dr. M. R. Fenske  
CONTRACT: NOrd 7958(B) (Joint Air Force-Navy)  
CONTRACTOR: Pennsylvania State College

TR 5655 (R)

December 1947

SUBJECT: HYDRAULIC FLUIDS, LUBRICANTS, FUELS AND RELATED MATERIALS.  
INVESTIGATOR: Dr. M. R. Fenske  
CONTRACT: NOrd 7958(B) (Joint Air Force-Navy)  
CONTRACTOR: Pennsylvania State College

TR 5746 (R)

January 1949

SUBJECT: POLYHALO ORGANIC COMPOUNDS AS LESS FLAMMABLE AIRCRAFT  
HYDRAULIC FLUIDS.  
INVESTIGATOR: James C. Mosteller

TR 5756 (R)

January 1949

SUBJECT: HYDRAULIC FLUIDS, LUBRICANTS, FUELS AND RELATED MATERIALS.  
INVESTIGATOR: Dr. M. R. Fenske  
CONTRACT: NOrd 7958(B) (Joint Air Force-Navy)  
CONTRACTOR: Pennsylvania State College

TR 5756, Supplement 1 (R)

September 1949

SUBJECT: HYDRAULIC FLUIDS, LUBRICANTS, FUELS AND RELATED MATERIALS.  
INVESTIGATOR: Dr. M. R. Fenske  
CONTRACT: NOrd 7958(B) (Joint Air Force-Navy)  
CONTRACTOR: Pennsylvania State College

TR 5763, Supplement 1 (R)

May 1950

SUBJECT: CHLORINE AND FLUORINE CONTAINING ORGANIC COMPOUNDS FOR NON-  
FLAMMABLE MATERIALS.  
INVESTIGATOR: E. T. McBee, et al.  
CONTRACT: W33-038-ac-19024  
CONTRACTOR: Purdue Research Foundation

PETROLEUM PRODUCTS, LUBRICANTS

TR 5685 (Uncl)

April 1948

SUBJECT: APPARENT VISCOSITY OF GREASES.  
INVESTIGATOR: Bernard Rubin

PLASTICS, STRUCTURAL

TR 4648 (Uncl)

June 1941

SUBJECT: MECHANICAL PROPERTIES OF PLASTIC MATERIALS AT NORMAL AND  
SUBNORMAL TEMPERATURES.  
INVESTIGATOR: Robert T. Schwartz, Donald A. Shinn, and Ture T. Oberg

TR 4969 (Uncl)

July 1943

SUBJECT: PROPERTIES OF EXTRUDED THERMOPLASTIC PLASTIC TUBINGS.  
INVESTIGATOR: Howard S. Bergen, Jr., 1/Lt.

TR 4989 (Uncl)

July 1943

SUBJECT: CREEP AND TIME FRACTURE STRENGTH OF PLASTIC MATERIALS UNDER  
TENSILE STRESSES.  
INVESTIGATOR: Bernard Chasman

TR 4998 (Uncl)

August 1943

SUBJECT: BEARING STRENGTH OF PLASTIC MATERIALS.  
INVESTIGATOR: R. T. Schwartz and Edward Dugger, Jr.

TR 5004 (Uncl)

September 1943

SUBJECT: SHEAR STRENGTH OF PLASTIC MATERIALS.  
INVESTIGATOR: R. T. Schwartz and Edward Dugger, Jr.

TR 5012 (Uncl)

August 1943

SUBJECT: IMPACT DATA FOR PLASTIC MATERIALS AT VARIOUS TEMPERATURES.  
INVESTIGATOR: Donald A. Shinn

TR 5062 (Uncl)

December 1943

SUBJECT: VARIATION OF TENSILE STRENGTH AND ELONGATION OF PLASTIC  
MATERIALS WITH TEMPERATURE.  
INVESTIGATOR: Robert T. Schwartz

TR 5077 (Uncl)

January 1944

SUBJECT: PLASTICS IN AIRCRAFT.  
INVESTIGATOR: Jean B. Cahan

TR 5698 (Uncl)

May 1948

SUBJECT: EFFECT OF OUTDOOR EXPOSURE ON FLEXURAL AND OTHER PROPERTIES  
OF SOME PLASTIC MATERIALS.  
INVESTIGATOR: John K. Long

TR 5748 (Uncl)

January 1949

SUBJECT: PROPERTIES OF GLASS FABRIC REINFORCED LOW PRESSURE LAMINATES.  
INVESTIGATOR: C. D. Jones  
CONTRACT: W535-ac-37069  
CONTRACTOR: Owens-Corning Fiberglas Corporation

TR 5940 (Uncl)

November 1949

SUBJECT: FLEXURAL PROPERTIES OF SOME GLASS FABRIC BASE PLASTIC LAMI-  
NATES AT ELEVATED TEMPERATURES.  
INVESTIGATOR: B. M. Axilrod and M. A. Sherman  
CONTRACT: P. O. (33-038)-49-516-E  
CONTRACTOR: National Bureau of Standards

TR 5941 (Uncl)

February 1950

SUBJECT: DEVELOPMENT AND TEST OF LOW-PRESSURE MOLDED GLASS FABRIC BASE  
SILICONE PLASTIC LAMINATES.  
INVESTIGATOR: George E. Power  
CONTRACT: W33-038-ac-19948  
CONTRACTOR: The Formica Company

TR 6389 (Uncl)

April 1951

SUBJECT: SOME STATIC FATIGUE, AND CREEP TESTS OF A GLASS FABRIC LAMI-  
NATED WITH A POLYESTER RESIN.  
INVESTIGATOR: William N. Findley and Will J. Worley  
CONTRACT: W33-038-ac-21089  
CONTRACTOR: The Engineering Experimental Station, University of Illinois

TR 5686 (Uncl)

May 1948

SUBJECT: RAIN EROSION PROPERTIES OF PLASTIC MATERIALS, PARTS 1 AND 2.

INVESTIGATOR: R. T. Schwartz  
CONTRACT: W33-038-ac-114248, Exhibit "L"  
CONTRACTOR: Cornell Aeronautical Laboratories, Inc.

TR 6190 (Uncl)

April 1951

SUBJECT: A STUDY OF THE RAIN EROSION OF PLASTICS AND OTHER MATERIALS.  
INVESTIGATOR: John L. Beal and Norman E. Wahl  
CONTRACT: W33-038-514  
CONTRACTOR: Cornell Aeronautical Laboratories, Inc.

RADIOGRAPHY

TR 4539 (Uncl)

June 1940

Out of print.

TR 5441 (Uncl)

March 1946

SUBJECT: STUDY OF THE RADIOGRAPHIC PROCESS.  
INVESTIGATOR: Leonard W. Katz, 1/Lt.

RUBBER

TR 2938 (Uncl)

August 1928

SUBJECT: PUNCTURE PROOF INNER TUBES  
INVESTIGATOR: C. J. Cleary

TR 3269 (Uncl)

June 1930

SUBJECT: LOAD COMPRESSION CHARACTERISTICS OF SHOCK ABSORBER DISCS.  
INVESTIGATOR: C. J. Cleary and C. J. Yeager

TR 3893 (Uncl)

September 1933

SUBJECT: RUBBER SUBSTITUTES AND SYNTHETICS IN AIRCRAFT FUEL LINES,  
INVESTIGATOR: C. J. Cleary

TR 4860 (Uncl)

November 1942

SUBJECT: PROPERTIES OF THE SYNTHETIC RUBBERS.  
INVESTIGATOR: P. J. Mahoney, J. I. Wittebort, and C. E. Jaynes

TR 5891 (Uncl)

May 1949

SUBJECT: INVESTIGATION OF RUBBER PLASTICIZERS FOR LOW TEMPERATURE APPLICATIONS.  
INVESTIGATOR: Earl R. Bartholomew

STRUCTURES

TR 5544 (Uncl)

January 1947

SUBJECT: REVIEW OF THE PROBLEMS OF SPECIFICATION, INSPECTION AND PROCUREMENT.  
INVESTIGATOR: Don Brouse, Lt. Colonel

TESTS, NONDESTRUCTIVE

TR 5598 (Uncl)

June 1947

SUBJECT: COMPARISON OF FLUORESCENT PENETRANT AND MAGNETIC PARTICLE INSPECTION METHODS.  
INVESTIGATOR: Edward Dugger

TR 5898 (Uncl)

July 1949

SUBJECT: THE APPLICATION OF STATIFLUX FOR NONDESTRUCTIVE INSPECTION OF NONCONDUCTING AIRCRAFT MATERIALS.  
INVESTIGATOR: Edward Dugger

TEXTILES

TR 2123 (Uncl)

March 1923

SUBJECT: DEVELOPMENT OF MANILA BALLOON ROPE.  
INVESTIGATOR: C. J. Cleary

TR 2291 (Uncl)

February 1924

SUBJECT: AIRPLANE LACING CORDS.  
INVESTIGATOR: C. J. Cleary

TR 2429 (Uncl)

October 1924

SUBJECT: PRELIMINARY REPORT ON POROSITY OF PARACHUTE FABRICS.  
INVESTIGATOR: George W. Polk, Jr., 1/Lt.

TR 2920 (Uncl)	July 1928
SUBJECT: STATISTICAL METHOD OF INSPECTION OF PARACHUTE SILK.	
INVESTIGATOR: C. J. Cleary	
TR 3089 (Uncl)	June 1929
SUBJECT: EFFECT OF SUNLIGHT ON PARACHUTE SILK.	
INVESTIGATOR: C. J. Cleary	
TR 3108 (Uncl)	July 1929
SUBJECT: PRELIMINARY STUDY OF THE POROSITY OF PARACHUTE FABRICS.	
INVESTIGATOR: C. J. Cleary	
TR 4620 (Uncl)	March 1941
SUBJECT: PHYSICAL PROPERTIES OF NYLON MATERIALS DEVELOPED FOR AIR CORPS USE.	
INVESTIGATOR: J. Edward Gill	
TR 5590 (Uncl)	June 1947
SUBJECT: TREATMENT OF NYLON WEBBING TO INCREASE RESISTANCE TO ABRASION.	
INVESTIGATOR: C. A. Willis	
TR 5665 (Uncl)	January 1948
SUBJECT: POROSITY CHARACTERISTICS OF PARACHUTE MATERIALS.	
INVESTIGATOR: H. G. Battles	
TR 5699 (Uncl)	May 1948
SUBJECT: TREATMENT OF NYLON WEBBING TO INCREASE RESISTANCE TO ABRASION.	
INVESTIGATOR: C. A. Willis	
TR 5894 (Uncl)	October 1950
SUBJECT: TEXTILES: ACCELERATED WEATHERING VERSUS OUTDOOR EXPOSURE TESTS.	
INVESTIGATOR: Joyce C. McGrath	
CONTRACT: AF 33(038)-16956	
CONTRACTOR: New Mexico State College of Agriculture and Mechanic Arts	



TRANSPARENT MATERIALS

TR 4604 (Uncl)

January 1941

SUBJECT: MONOMERIC CEMENT FOR BONDING ACRYLATE PLASTICS.  
INVESTIGATOR: E. J. Wyrostek

TR 5108 (Uncl)

April 1944

SUBJECT: MEASUREMENT OF OPTICAL HAZE IN TRANSPARENT MATERIALS.  
INVESTIGATOR: Leah K. Hendriksen

SECTION III

ADDITIONAL REPORTS

ALLOYS, NONFERROUS, MAGNESIUM

TR 4514 (Uncl)

February 1940

SUBJECT: MAGNESIUM ALLOY EXTRUDED SECTION - (ALUMINUM ZINC MAGNESIUM  
A.M.C.-57S).  
INVESTIGATOR: D. M. Warner

TR 5926 (Uncl)

November 1950

SUBJECT: MECHANICAL PROPERTIES OF EXTRUDED MAGNESIUM ALLOYS - ZK60 AND  
AZ80.  
INVESTIGATOR: W. J. Trapp

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